Chapter 3.0 National Emissions Trends, 1900 to 1998

3.1 WHAT DATA ARE PRESENTED IN THIS CHAPTER?

This chapter presents historical trends in air pollutant emissions [carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOCs), sulfur dioxide (SO_2), particulate matter less than 10 microns (PM_{10}), particulate matter less than 2.5 microns ($PM_{2.5}$), and lead (Pb). Although not a criteria pollutant, emission estimates for ammonia (NH_3)] for the period 1900 through 1998 (where available). The source categories discussed in this chapter include: fuel combustion, industrial processes (chemical and allied products, metals processing, petroleum and related industries, other industrial processes, solvent utilization, storage and transport, and waste disposal and recycling), on-road vehicles, non-road engines and vehicles, and miscellaneous. This chapter also describes the effects that national economic activity and regulatory efforts have had on air pollutant emissions trends.

In this chapter, values representing changing emissions or the percentage change in emissions over various time periods are presented. It is important for the reader to realize that all values are estimates only and possess a large degree of uncertainty. Uncertainty analyses are ongoing at the United States (U.S.) Environmental Protection Agency (EPA) and will be reported in the FY2001 report.

3.2 WHEN DID AIR POLLUTION CONTROL EFFORTS BEGIN AND HOW HAVE THEY EVOLVED?

In 1881, the cities of Chicago and Cincinnati, in an effort to control smoke and soot primarily from furnaces and locomotives, passed the first air pollution statutes in the United States. By the early 1900s, county governments began to pass their own pollution control laws. In 1952, Oregon became the first state to legislatively control air pollution, and other states soon followed, enacting air pollution statutes generally aimed at controlling smoke and particulates.

The Federal Government became involved in air pollution control in 1955 with the passage of the Air Pollution Control Act. This law limited Federal involvement in air pollution control to providing funding assistance for the States' air pollution research and training efforts. The shift by the Federal Government toward greater involvement in air pollution control began with the passage of the original Clean Air Act (CAA) in 1963. This act provided permanent Federal support for air pollution research, continued and increased Federal assistance to states for developing their air pollution control agencies, and a mechanism through which the Federal Government could assist states with cross-boundary air pollution problems. In 1965, Congress amended the CAA for the first time, directing the Secretary of Health, Education, and Welfare to set the first Federal emissions standards for motor vehicles.

In 1967, Congress passed the Air Quality Act, which required that states establish air quality control regions and that Health, Education, and Welfare, through the National Air Pollution Control Administration, conduct research on the effects of air pollution, operate a monitoring network, and promulgate criteria to serve as the basis for setting emission standards. States would then use the HEW information to set air quality standards. In addition, the Air Quality Act directed HEW to identify control technologies for states to use to attain the air quality standards that each state was to have established.

Several problems undermined this early period of federal air pollution control. The HEW belatedly issued guidance documents detailing the adverse health effects associated with common air pollutants; where guidance documents had been prepared, states either failed to set air quality standards or failed to develop implementation plans in a timely manner. In addition, the initial exhaust emission standards set by HEW in 1968 resulted only in relatively small reductions in automobile pollutants.

1970 marked the beginning of several major changes to federal air pollution control efforts. First, the Federal Government created a new federal agency, the EPA, on December 2, 1970, and charged it with the responsibility of setting National Ambient Air Quality Standards (NAAQS). Second, EPA was given the authority to develop national emissions standards for cars, trucks, and buses. Finally, Congress gave EPA the power to set emissions performance standards [known as new source performance standards (NSPS)] for all new sources of the common air pollutants. Under the CAA, the only major responsibility that states

retained was that of determining how to control existing sources.

In response to its mandate, the EPA promulgated primary and secondary NAAQS in 1971 for photochemical oxidants, SO_2, total suspended particulate (TSP), CO, and hydrocarbons. To comply with each of the NAAQS by a 1975 deadline, states had to develop and implement State Implementation Plans (SIPs) that would demonstrate how existing sources would be controlled. In 1977, Congress made additional modifications to the CAA, laying the groundwork for more significant changes to occur with the passage of the CAA Amendments (CAAA).

The photochemical oxidants standard formulated by EPA in 1971 set an hourly average level that was not to be exceeded more than once per year. In 1979, EPA changed the chemical designation of the NAAQS from photochemical oxidants to ozone (O_3). In 1979, EPA revised the O_3 standard from 0.08 parts per million (ppm) of O_3 to 0.12 ppm of O_3 measured over a 1-hour period, not to be exceeded more than three times in a 3-year period. In July 1997, EPA once again revised the O_3 standard, returning it to 0.08 ppm of O_3 but measured over an 8-hour period, where a formal exceedance was triggered by the fourth highest concentration over a 3-year period. The District of Columbia Circuit Court remanded this revision in May of 1999, placing the status of the new 8-hour O_3 NAAQS in question.

The regulatory discussion in this report is not comprehensive; instead, it emphasizes some of the regulatory efforts that have targeted the major source categories for each air pollutant. An example is the national Acid Rain Program authorized by Title IV of the 1990 CAAA. The initial phase of its innovative market-based SO_2 reduction program began in 1995 and, during the first year of compliance, utilities cut SO_2 emissions from their Phase I (Table A) units by approximately 40 percent. Phase I of the Acid Rain NO_x reduction program, a more conventional rate-based control program for coal-fired utility boilers, began in 1996 and contributed to the general decline in NO_x emissions in the late 1990s.

However, the lack of detail available for all of the data precludes the possibility of analyzing some of the stationary source control measures [for example, state-specific regulations such as reasonably available control technology (RACT) provisions]. As a point of reference, Figure 3-1 presents the trends in gross domestic product (GDP), population, vehicle miles traveled (VMT), and total fuel consumption (that is, total fuel consumed by industrial, residential, commercial, and transportation sectors) from 1970 to 1998.

In the fall of 1998, EPA issued a new regulation requiring 22 states and the District of Columbia to submit SIPs to diminish the regional transport of ground-level O_3 through reductions in NO_x. This regulation is commonly known as the NO_x SIP call. By reducing NO_x emissions, this rule aims to reduce the transport of ground-level ozone across state boundaries in the eastern half of the United States. The rule requires NO_x emission reduction measures to be in place by May 1, 2003. While EPA does not mandate which sources must reduce pollution, EPA expects utilities and large non-utility point sources to be the most likely sources of NO_x emissions reductions. The rule also establishes a NO_x Budget Trading Program which should enable states to achieve over 90 percent of the required emissions reductions in a highly cost-effective manner. EPA projects that full implementation of the NO_x SIP call would reduce NO_x emissions in the eastern United States by 25 percent, or approximately 1.142 million tons, beginning in the year 2003. Timing is uncertain due to litigation.

3.3 WHAT ARE THE GENERAL HISTORICAL EMISSIONS TRENDS?

Tables 3-1 through 3-8 present emissions trends for the period 1940 through 1998 for CO, NO_x, VOC, SO_2, PM_{10}, $PM_{2.5}$, Pb, and NH_3. Appendix Tables A-1 through A-7 present detailed emissions for the years 1970 through 1998, "where available." CO, VOC, SO_2, and Pb emissions peaked in or around 1970, with a general downward trend during the 1970 to 1998 time frame. PM_{10} emission levels peaked around 1950, steadily declined until the mid-1980s, and since then have remained relatively stable. NO_x emissions steadily increased through the mid-1970s to 24.4 million tons in 1980, declined slightly during the early 1980s, and then climbed again, exceeding 25 million tons in 1994. Total NO_x emissions have since declined slightly. From 1990 to 1998, NH_3 emissions rose by 14 percent, while $PM_{2.5}$ emissions remained relatively stable. Figures 3-2 through 3-9 depict emission estimates for each source category from 1940 to 1998 (where available).

3.3.1 How Have CO Emissions Changed?

Table 3.1 shows historical trends in CO emissions by principal source categories. Total CO emissions peaked in 1970 and decreased rather steadily thereafter. A significant decrease in CO emissions occurred between 1973 and 1975 as a result of disruptions in world oil markets and a subsequent recession in the United States. (NO_x and VOC emissions trends also showed similar short-term decreases from 1973 to 1975 for the same reasons.) The fluctuations of CO emissions in the late 1980s is due to the variation in wildfire activity from year-to-year.

3.3.2 How Have NO_x and VOC Emissions Changed?

This report often considers NO_x and VOC together because they comprise the principal components in the chemical and physical atmospheric reactions that form O_3 and other photochemical oxidants. Although an ambient air quality standard does not exist for VOC, VOC emissions are an important category from the standpoint of modeling O_3 formation.

With regard to NO_x, total national emissions increased 233 percent between 1940 and 1998. Changes in emissions over this time period are shown in Table 3-2. From 1970 to 1997, NO_x emissions increased by approximately 19 percent, followed by a slight decline in 1998.

Table 3-3 presents the trend in VOC emissions from 1940 through 1998. Total national VOC emissions rose significantly from 1940 to 1970, but then declined almost as significantly from 1970 to 1998. In fact, 1998 levels exceed 1940 VOC emission levels by less than one million tons.

When calculating VOC emissions, EPA includes those emissions of VOC species that primarily contribute to the formation of O_3 in total VOC emissions but excludes emissions of methane (CH_4), a nonreactive compound. EPA makes no adjustments to include chlorofluorocarbons (CFCs) or to exclude ethane and other VOCs with negligible photochemical reactivity, and it estimates on-road vehicle emissions as nonmethane hydrocarbons. Chapter 6 discusses emissions of organic compounds from biogenic sources such as trees and other vegetation. According to recent research, natural sources emit almost the same level of VOC emissions as anthropogenic sources, but the extent to which biogenic VOC emissions contribute to oxidant formation has not been determined.

3.3.3 How Have SO_2 Emissions Changed?

Table 3-4 presents the trend in SO_2 emissions between 1940 and 1998. National SO_2 emissions rose 56 percent from 1940 to 1970 and have since declined, primarily because of regulatory actions, especially those that targeted utility sources.

3.3.4 How Have PM_{10} Emissions Changed?

Table 3-5 presents the 1940 to 1998 trend in PM_{10} emissions. EPA divides PM_{10} sources into two categories: fugitive dust sources and nonfugitive dust sources. PM_{10} fugitive dust sources include natural sources (geogenic - wind erosion) and some miscellaneous sources. These miscellaneous sources include agriculture and forestry fugitive dust sources. The PM_{10} nonfugitive dust sources include all other PM_{10} sources. For 1998, EPA estimates that total national fugitive dust PM_{10} emissions are approximately 8 times greater than total emissions from nonfugitive dust sources. Since 1990, emissions from fugitive dust sources have increased slightly, primarily as the result of increases in unpaved road and construction emissions.

3.3.5 How Have $PM_{2.5}$ Emissions Changed?

This most recent Trends report includes data on $PM_{2.5}$ emission trends since 1990. EPA originally developed emissions estimates for $PM_{2.5}$ under the National Particulate Inventory (NPI). This study consisted of a 1990 air emissions inventory for the United States (excluding Alaska and Hawaii), Canada, and Mexico. For the *1998 Trends* report, EPA uses State particulate data where available to develop $PM_{2.5}$ estimates. As can be seen in Table 3-6, overall $PM_{2.5}$ emissions remain relatively constant from 1990 to 1998, while emissions from residential wood combustion decline significantly and emissions from natural sources fluctuate.

3.3.6 How Have Pb Emissions Changed?

Table 3-7 provides data on Pb emissions from 1970 through 1998. The promulgation of a national ambient air quality standard for Pb in October 1978 has been the primary force behind the dramatic decrease in Pb emissions from 220,869 tons in 1970 to 3,973 tons in 1998.

3.3.7 How Have NH_3 Emissions Changed?

This Trends report also includes data on NH_3 emission trends since 1990. Table 3-8 presents the emissions data for NH_3 since 1990. Fuel combustion-industrial, on-road vehicles, and miscellaneous sources saw the greatest growth in emissions during the 1990s, while chemical and allied product manufacturing and petroleum and related industries saw the greatest declines in emissions during that same period.

3.4 HOW HAVE EMISSIONS IN THE MAJOR SOURCE CATEGORIES CHANGED?

This section discusses the trends in emissions from a source category perspective rather than a pollutant perspective. While each pollutant is discussed relative to the source category being considered, the main emphasis is on the changes that have occurred in that source category. In addition, this section occasionally discusses long term trends in emissions. As a point of reference, Table 3-13 presents total national (but not source category specific) emission estimates for each pollutant for each year available from 1900 to 1998.

3.4.1 How Have Emissions in the Stationary Source Fuel Combustion Categories Changed?

The three stationary source fuel combustion categories are fuel combustion - electric utility, fuel combustion - industrial, and fuel combustion - other. Fuel combustion - other includes commercial/institutional coal, commercial/institutional oil, commercial/institutional gas, miscellaneous fuel combustion (except residential), residential wood and residential other. Figures 3-2 through 3-9, present trends in CO, NO_x, VOC, PM, $PM_{2.5}$, Pb, and NH_3 emissions from fuel combustion sources from as early as 1940 in most cases, to 1998.

Emissions of SO_2 from fuel combustion sources peaked in 1973, declined sharply in the mid 1990s, but are rising again. NO_x emissions from fuel combustion sources peaked a few years later, in 1977, and remained approximately constant at their peak level through the mid 1990s. Meanwhile, VOC and PM_{10} emissions declined steadily from 1940 until the early 1970s. Emissions then rose, but declined again in the late 1980s. Pb emissions peaked in 1972 and have since declined significantly. Although overall CO emissions declined steadily from 1940 until 1970, they reversed trend after 1970, peaking at 8 million tons in 1985. $PM_{2.5}$ emissions have declined overall between 1990 and 1998. While NH_3 emissions from fuel combustion sources rose slightly since 1990, fuel combustion contributed less than 2 percent to national total NH_3 emissions throughout the 1990s.

Historically, residential wood contributes the largest quantity of fuel combustion CO and VOC emissions. Therefore, despite a gradual increase in CO and VOC emissions from electric utilities and industrial sources since 1940, the more substantial decline in emissions from residential wood consumption since 1985 accounts for the overall decline from the fuel combustion category since 1985. CO and VOC emissions from the fuel combustion category accounted for 16 and 12 percent of total national CO and VOC emissions in 1940 but only 6 and 5 percent in 1998.

In 1900, emissions from all fuel combustion sources represented 68 percent of total national VOC emissions, with residential wood combustion accounting for 90 percent of those emissions. From 1940 to 1970, residential wood consumption declined steadily as a result of the abundant supply, low relative prices, and convenience of fossil fuels relative to wood for home heating, cooking, and heating water. This decline halted in the early 1970s because disruptions in crude oil deliveries and related product markets caused prices for fossil fuel products to rise. These higher prices led to a resurgence in the use of wood for home heating and thus to a corresponding increase in emissions from residential wood combustion. By 1980, though, prices of fossil fuel products once again began to decline. As a result, residential wood consumption once again declined, as did the corresponding CO and VOC emissions.

With regard to NO_x, electric utilities contribute the largest percentage of NO_x emissions from the stationary source fuel combustion categories. In 1900, electric utilities accounted for 4 percent of total national 1998 NO_x emissions, but by 1998 they accounted for 25 percent of total national NO_x emissions. Coal accounted for 88 percent of the electric utility NO_x emissions in 1998.

Fuel combustion-industrial contributes approximately 12 percent of total national 1998 NO_x emissions. While emissions from this source have generally declined since 1970, they rose slightly from 1992 to 1996 (see Appendix Table A-2). Meanwhile, NO_x emissions from fuel combustion - other generally increased since 1940, although a small decline has occurred since 1992. Fuel combustion - other contributed less than 5 percent of total national NO_x emissions in 1998.

As with NO_x emissions, electric utilities contributed 4 percent of total national SO_2 emissions in 1900. These emissions increased by a factor of 5 over the period 1900 to 1925, but the onset of the Great Depression put a halt to the growth in these emissions during the 1930s. As the United States recovered from the Depression, emissions from electric utilities once again rose. By 1940, SO_2 emissions levels approximated pre-1930 levels. From 1940 to 1970, SO_2 emissions from electric utilities doubled every decade as a result of increased coal consumption. By 1970, emissions from coal combustion accounted for more than 90 percent of total SO_2 emissions from electric utilities. With the help of regulatory controls, SO_2 emissions from electric utilities using all types of energy sources decreased approximately 38 percent from 1970 to 1996 (see Table A-4). Despite this decrease, electric utilities still accounted for 67 percent of the total national SO_2 emissions in 1998.

In 1940, PM_{10} emissions from fuel combustion represented approximately 31 percent of nonfugitive dust PM_{10} emissions. Electric utility PM_{10} emissions derive primarily from the combustion of coal. Emissions from this electric utilities increased by approximately 85 percent between 1940 and 1970, which corresponds to an increase in electric production using coal as an energy source during the same time period. Fuel combustion PM_{10} emissions have since declined from 1970 levels. In terms of $PM_{2.5}$, overall fuel combustion emissions remained fairly steady from 1990 through 1998. Fuel combustion sources contributed 9 percent of total national 1998 $PM_{2.5}$ emissions

Fuel combustion sources accounted for 5 percent of total national Pb emissions in 1970. Despite a 95 percent decline since 1970, fuel combustion sources still accounted for 13 percent of total national Pb emissions in 1998. Fuel combustion's contribution to total NH_3 emissions remained less than 2 percent throughout the 1990 to 1998 time frame.

The overall decline in emissions from fuel combustion sources since the 1970s can be attributed to various regulatory actions. As mentioned previously, SO_2 emissions from electric utilities using all types of energy sources decreased

approximately 24 percent from 1970 to 1998. The SO_2 NAAQS, promulgated in 1971, served as a primary factor in reducing SO_2 emissions. Another factor was EPA's development of a NSPS in 1971. This NSPS required that all new coal-fired power plants emit no more than 1.2 pounds of SO_2 per each million British thermal units (Btus) of electricity produced. Most new plants chose to meet this NSPS by shifting to lower-sulfur coals. An amendment to the CAA in 1977 effectively required any new coal-fired power plant not only to meet the original NSPS, but also to use some form of scrubbing equipment, even when using low-sulfur coal. Beginning in December 1976, a NSPS for new, modified, or reconstructed fossil-fuel-fired steam generators became effective, further promoting reductions in fuel combustion emissions. To help reduce PM emissions, EPA promulgated a TSP NAAQS in 1971. In 1987, EPA revised the TSP standard to include only PM_{10}.

As a result of EPA's regulations, SO_2 and PM_{10} emissions from coal-fired electric power facilities fell by 8 and 85 percent, respectively, between 1970 and 1993, despite the fact that consumption of coal to produce electricity increased 150 percent during that same period.[2]

Title IV (Acid Deposition Control) of the CAAA is an important factor in the decline in SO_2 emissions from fuel combustion sources and has contributed to the general decline of NO_x emissions. Title IV specifies that annual SO_2 emissions must decrease by 10 million tons from 1980 emissions levels and suggests, as a guideline, that annual NO_x emissions be reduced by 2 million tons from 1980 levels. Title IV defines two stages by which SO_2 reductions must occur. Phase I, which affects 263 mostly coal-fired units, began January 1, 1995. Phase II, which applies to the remaining affected Title IV units, began January 1, 2000. To achieve these reductions in a cost effective manner, utilities may choose from among a variety of possibilities, including participating in a market-based allowance trading system.[3]

Many utilities switched to low sulfur coal and some installed flue gas desulfurization equipment (also known as scrubbers) for their Phase I units, thereby achieving reductions in SO_2 emissions greater than those required under Title IV. These changes enabled utilities to reduce SO_2 emissions from their Phase I units from 7.4 million tons in 1994 to 4.5 million tons in 1995, the first year of compliance.

3.4.2 How Have Emissions in the Industrial Process Categories Changed?

Industrial processes include the following Tier 1 categories: chemical and allied products; metals processing; petroleum and related industries; other industrial processes; solvent utilization; storage and transport; and waste disposal and recycling.

CO, NO_x, and VOC emissions from industrial processes peaked in 1950, 1960, and 1980, respectively. Industrial processes accounted for 12 percent of total national CO emissions in 1940 and 13 percent in 1970, but only 5 percent of total national CO emissions in 1998. With regard to NO_x emissions, industrial processes historically account for only a small percentage of the national total. Industrial processes accounted for an increasing share of national VOC emissions between 1900 and 1970. Although VOC emissions from industrial process sources declined by 41 percent from 1970 to 1998, they still account for 47 percent of total national VOC emissions. Emission control devices and process changes contributed to the decline in actual VOC emissions since 1970.

CO emissions from petroleum and related industries increased by a factor of 10 between 1940 and 1970 due to increases in refinery throughput and in demand for refined petroleum products. Since 1970, CO emissions from the petroleum refining industry have decreased by 83 percent due to the installation of emission control devices such as fluid catalytic cracking units and the retirement of obsolete high polluting processes such as the manufacture of carbon black by channel process. By 1998, petroleum refining accounted for less than 1 percent of total national CO emissions.

As mentioned previously, industrial processes account for only a small percentage of the national total NO_x emissions. Within the industrial process category, though, waste disposal and recycling contributed the highest percentage of NO_x emissions from 1940 to 1970. NO_x emissions from the waste disposal and recycling category increased by 300 percent from 1940 to 1970, but then decreased by 78 percent from 1970 to 1998 to less than 1940 levels. After 1970, the other industrial processes category surpassed waste disposal and recycling as the biggest contributor of industrial process NO_x emissions. The 34 percent increase in NO_x emissions from industrial processes from 1980 to 1998 occurred partly because of a change in the methodology used to estimate emissions between 1984 and 1985.

Emissions of VOCs from petroleum and related industries and petroleum product storage and marketing operations increased during the mid-1970s as a result of increased demand for petroleum products, especially motor gasoline. After 1980, the emissions from these sources decreased as the result of product reformulation and the implementation of pollutant control measures.

Industrial process SO_2 emissions peaked in 1970, when they contributed approximately 23 percent of the total national SO_2 emissions. From 1970 to 1998, emissions decreased by 79 percent, and by 1998 industrial processes only contributed 8 percent of the national total SO_2 emissions.

A major reason for the decline in industrial process SO_2 emissions since 1970 comes from the decline in metals processing emissions. Although SO_2 emissions from metals processing increased by 44 percent over the period 1940 to 1970, they decreased by almost 91percent from 1970 through 1998 due to the increased use of emission control devices. By 1998, metals processing accounted for approximately 2 percent of total national SO_2 emissions in 1998, down from 15

percent in 1970. In addition, SO_2 emissions from nonferrous smelters have fallen significantly. By-product recovery of sulfuric acid at these smelters has increased since 1970, resulting in the recovered sulfuric acid not being emitted as SO_2.

Historically, copper processing contributed the largest percentage of metals processing SO_2 emissions. To control copper processing SO_2 emissions, EPA issued a NSPS to regulate SO_2 emissions from copper smelters built, modified, or reconstructed after October 16, 1974. As a result, SO_2 emissions from copper production facilities declined almost 97 percent between 1970 and 1998, even though copper production only declined by 15 percent during the time period (1970 to 1993).[4]

Emissions of SO_2 from chemical and allied manufacturing, petroleum and related industries, and other industrial processes accounted for 4 percent of total SO_2 emissions in 1940 and 7 percent in 1970. Since 1970, SO_2 emissions from these sources have declined by 56 percent. The NSPS issued for sulfuric acid manufacturing plants built, modified, or reconstructed after 1972 is one major factor contributing to this decline.

PM_{10} emissions from industrial processes increased from 1940 to 1960, primarily as a result of increased industrial production. From 1960 to 1970, industrial output continued to grow, but PM_{10} emissions began to decline due to the installation of pollution control equipment mandated by state and local air pollution control programs. This decline was very slight, though, because the rise in emissions due to production increases more than offset the decline in emissions caused by the control devices.

In 1970, industrial processes contributed 66 percent of total national nonfugitive dust source PM_{10} emissions. By 1998, this contribution had decreased to 26 percent, reflecting the significant progress achieved in reducing emissions from industrial processes.

$PM_{2.5}$ emissions from industrial processes have remained fairly steady throughout the 1990s, although emissions from all industrial process categories declined slightly between 1995 and 1998.

In 1970, the industrial process group's Pb emissions were 13 percent of almost 221 thousand tons, nationally. Seventy-eight percent of this national total came from the on-road vehicles category which, by 1998 had been reduced to a mere 19 tons per year. Thus, while industrial process emissions of Pb have been reduced by 90 percent by 1998, they now represent 74 percent of the more dramatically reduced national total of less than 4 thousand tons per year.

Similar to $PM_{2.5}$ emissions, emissions of NH_3 from industrial process remained fairly steady throughout the 1990s. Emissions from all industrial process categories except other industrial processes declined slightly between 1995 and 1998.

3.4.3 How Have Emissions in the On-road Vehicle Categories Changed?

Historically, on-road vehicles have contributed significant amounts to national CO, NO_x, VOC, PM (if only nonfugitive dust emissions are considered), and Pb emissions levels but only small amounts to national SO_2 emission levels. The increasing popularity of motorized vehicles during the first half of the 20th century led to a corresponding increase in emissions from these vehicles.

Motorized vehicles became so popular that by 1970, on-road vehicles accounted for 35 percent of total NO_x emissions, 68 percent of total CO emissions, 42 percent of total VOC emissions, and 78 percent of total Pb emissions.

In an effort to control rising emissions levels, in the early 1970s EPA developed CO, NO_x, and VOC emission limits for on-road vehicles. Table 3-9 lists the CO emission standards, expressed in grams per mile (gpm), for light-duty vehicles (LDV) and light-duty trucks (LDT). Table 3-10 and Table 3-11 list the NO_x and VOC emissions limits for LDVs and LDTs, respectively. In addition to these limits, LDTs greater than 6,000 pounds and heavy-duty trucks must also meet NO_x emissions standards. The Federal CO standards through 1975 applied only to gasoline-powered LDTs, whereas federal standards for 1976 and later applied to both gasoline and diesel-powered LDTs. In addition, EPA requires that 1984 and later model years meet a CO standard of 0.50 percent at idle (effective with the 1988 model year at higher altitudes). Similar to the NO_x standards, other CO standards apply to LDTs more than 6,000 lbs, heavy-duty engines and vehicles, and non-road engines and vehicles.

With regard to additional CO emissions controls, the CAAA requires cars to meet a standard of 10 gpm at 20 degrees Fahrenheit, starting with the 1996 model year. This standard helps ensure that vehicular emission control devices work efficiently at low temperatures.

In general, the emission limits set by EPA resulted in significant decreases since 1970 in CO and VOC emitted by on-road vehicles. Since 1970, CO and VOC emissions from on-road vehicles have declined by almost 43 and 59 percent, respectively. NO_x emissions from on-road vehicles peaked in the late 1970s but have declined slightly since then. Although NO_x emissions levels from on-road vehicles are slightly higher than in 1970, VMT has more than doubled since 1970. The federal NO_x emissions standards have succeeded in keeping emissions growth in check.

To achieve more significant NO_x emissions reductions, EPA issued new federal tailpipe emissions standards in December 1999 for passenger cars, light trucks, and larger passenger vehicles. These standards, known as Tier II standards, should help reduce air pollution. These standards will take effect beginning in 2004 and will apply to both cars and light-duty trucks, including sport utility vehicles (SUVs).

Under the Tier II standards, affected vehicles must meet a 0.07 gpm standard for NO_x, which is a 77 percent reduction for cars and up to a 95 percent reduction for LDTs and SUVs. Vehicles weighing less than 6000 pounds will be phased-in to the new standard between 2004 and 2007. The heaviest LDTs will adopt a three-step approach, spanning from 2004 to 2009.

When it issued the Tier II standards, EPA also set new standards for sulfur levels in gasoline. Gasoline suppliers must meet an average sulfur level of 30 ppm by 2005, down from the current average of 300 ppm. The new sulfur levels will ensure the effectiveness of low emission-control technologies in vehicles. Auto makers and refiners will be allowed to meet these standards by averaging across the entire vehicle fleet and gasoline pool.

Pb emissions from on-road vehicles, which peaked in the early 1970s, have steadily decreased as the result of a series of regulatory actions that progressively reduced the Pb content of all gasoline. EPA mandates reduced the Pb content of gasoline dramatically, from an average of 1.0 gram per gallon (gpg) to 0.5 gpg on July 1, 1985, and still further to 0.1 gpg on January 1, 1986. In addition, as part of EPA's overall automotive emission control program, unleaded gasoline was introduced in 1975 for use in automobiles equipped with catalytic control devices, which help reduce CO, VOC, and NO_x emissions. In 1975, unleaded gasoline's share of the total gasoline market totaled 13 percent. By 1982 this share had climbed to approximately 50 percent, and by 1996 (due to the CAAA prohibition on the use of leaded gasoline in highway vehicles after December 31, 1995) unleaded gasoline accounted for 100 percent of the total gasoline market.

Table A-6 (see Appendix A) shows that Pb emissions decreased dramatically between 1990 and 1991. This decrease is the result of large changes in the values for Pb in gasoline. Since the prohibition on Pb in gasoline did not officially begin until January 1, 1996, the reductions calculated for 1991 and later are primarily the result of limited data on trace Pb levels in gasoline for these years. Therefore, the full reduction that begins in 1991 may actually occur several years later.

Pb emissions from on-road vehicles have fallen significantly since the introduction of these regulations, and Pb emissions from on-road vehicles now account for less than 1 percent of national Pb emissions, down substantially from almost 82 percent of national emissions in 1980.

In an effort to reduce SO_2 and PM (as sulfate particles) emissions from on-road vehicles, EPA published a regulation on August 21, 1990, that governs desulfurization of diesel motor fuel. This regulation states that as of October 1, 1993, all diesel fuel that contains a concentration of sulfur in excess of 0.05 percent by weight or that fails to meet a minimum cetane index of 40 cannot be used in motor vehicles.[5] Since implementation of these desulfurization regulations, EPA has found that SO_2 emissions from diesel motor vehicles are reduced by approximately 75 percent.

In 1940, on-road vehicles accounted for just over 1 percent of nonfugitive dust PM_{10} emissions. Although the 1998 emissions from on-road vehicles represent 9 percent of the total national PM_{10} emissions from nonfugitive dust sources, PM_{10} emissions from on-road vehicles in1998 are approximately the same as those in 1940.

Absent regulation, it is reasonable to assume that a decrease in the price of gasoline will result in greater VMT, increased fuel use, and greater emissions, all other factors remaining unchanged. However, overall on-road vehicle emissions actually declined from 1970 to 1998, despite the fact that fuel use increased approximately 50 percent, VMT increased over 100 percent, and real gasoline prices decreased 17 percent during this same time period.[1] These trends indicate the success of regulations in reducing emissions from on-road vehicles.

3.4.4 How Have Emissions in the Non-road Engines and Vehicle Categories Changed?

Unlike emissions trends for on-road vehicles, emissions of CO, NO_x, and VOC from non-road engines and vehicles increased steadily from 1940 to 1996, with slight reductions in CO and VOC emissions over the past 2 years. SO_2 emissions declined by 97 percent from 1940 to 1970, but have since risen again, to about one third of 1940 levels. PM_{10} emissions declined significantly from 1940 to 1960, rose slightly in the period from 1960 to 1990, and have declined slightly since 1990. $PM_{2.5}$ emissions have remained relatively level for the past 8 years. Pb emissions declined approximately 91 percent between 1970 and 1985, and they have continued to decline slightly since 1985. NH_3 emissions from non-road engines and vehicle over the past 9 years are quite negligible.

Non-road engines and vehicles contributed 9 percent of total national CO emissions in 1940, with emissions from railroad locomotives accounting for approximately 51 percent of this amount. CO emissions from non-road vehicles and engines have increased 90 percent from 1940 levels and now account for 22 percent of the national total, but now non-road gasoline equipment engines are the predominant sources of non-road CO emissions.

In 1900, non-road engines and vehicles accounted for 4 percent of total national VOC emissions, of which railroad emissions contributed 99 percent. Railroad VOC emissions peaked in 1920 at 20 percent of the national total and have decreased since then to less than 1 percent currently. Although railroad emissions decreased, emissions from non-road engines and vehicles increased 216 percent during the 1940 to 1998 period. As a result, emissions from non-road engines and vehicles as a percentage of the national total climbed from approximately 5 percent in 1940 to approximately 14 percent in 1998.

Similarly to on-road vehicle NO_x emissions trends, emissions from non-road engines and vehicles increased over the period from 1940 to 1998. To help slow this growth in

emissions, EPA established emission control measures (Tier I standards) for new non-road diesel engines in certain horsepower categories. These standards began to take effect in 1996, with full phase-in for all horsepower categories scheduled for 2000. These controls should help reduce the amount of NO_x emissions emitted by these sources.

In 1940, SO_2 and PM_{10} emissions from non-road vehicles and engines both accounted for approximately 16 percent, respectively, of total national emissions for these two pollutants. Railroads contributed significantly to total 1940 SO_2 and PM_{10} emissions. From 1940 to 1970, SO_2 and PM_{10} emissions from railroads decreased by 99 percent as a result of the obsolescence of coal-fired locomotives. By 1998, non-road engines and vehicles represented only 1 percent of the total 1998 national PM_{10} emissions (16 percent of nonfugitive dust sources). While PM_{10} emissions from non-road engines and vehicles declined, so did PM_{10} emissions from most other nonfugitive dust sources.

3.4.5 How Have Emissions in the Miscellaneous Categories Changed?

In 1940, CO emissions from "miscellaneous other combustion - forest wildfires" accounted for 27 percent of total national CO emissions. Although relatively erratic from year to year due to the uncontrolled nature of wildfires, wildfire CO emissions declined from 1940 levels to only 3 percent of total national CO emissions in 1998. Similarly, annual PM_{10} emissions from wildfires vary depending upon the incidence of wildfires and upon weather conditions in forested areas.

Miscellaneous source emissions accounted for 13 percent of the total 1940 NO_x emissions. In 1998, the total emissions for the miscellaneous sources accounted for slightly more than 1 percent of national NO_x emissions.

In 1900, emissions from the miscellaneous sources category represented 24 percent of total VOC emissions. By 1998 they accounted for only 4 percent of national VOC emissions. With regard to SO_2 emissions, miscellaneous sources accounted for less than 3 percent of total national SO_2 emissions in 1940. By 1998, they contributed less than 0.1 percent of national SO_2 emissions. Pb emissions from other/miscellaneous sources account for a negligible amount of national Pb emissions. Meanwhile, miscellaneous emissions account for a substantial percentage of NH_3 emissions. From 1990 to 1998, emissions from miscellaneous sources rose 13 percent, and they accounted for 86 percent of total national NH_3 emissions in both 1990 and 1998.

3.5 HOW HAVE EMISSIONS IN THE FUGITIVE DUST CATEGORIES CHANGED?

Fugitive dust source emission estimates were first presented in the *1991 Trends* report. At that time, EPA based its emission estimates upon old emission factors and limited data. The methods EPA used to produce the estimates relied on State-level default data for most source categories. In the 1997 Trends report, EPA revised the methods used to produce post-1989 estimates in order to reflect improved emission factors, improved activity data, or both.

For several source categories, the methodology for estimating fugitive dust emissions utilizes meteorological data such as the number of days with greater than 0.01 inches of precipitation and average monthly wind speed. These data can vary significantly from year-to-year, resulting in highly variable emissions.

PM_{10} and $PM_{2.5}$ fugitive dust emissions can be determined from Tables 3-5 and 3-6 respectively. The categories that comprise the fugitive dust emission categories are identified in Chapter 1, section 1.4. As previously noted, estimates of PM_{10} fugitive dust prior to 1989 were based on crude methodologies and should be strongly discounted. PM_{10} emissions from fugitive dust sources decreased by 24 percent from 1985 to 1998 due primarily to the changes in emission methodologies for several of the fugitive dust sources, but also due to holding wind erosion constant from 1996 forward.

For 1998, EPA estimates total national fugitive dust PM_{10} and $PM_{2.5}$ emissions to be approximately 8 and 2 times higher, respectively, than total national nonfugitive PM_{10} and $PM_{2.5}$ emissions.

3.6 REFERENCES

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4. "Cement," *Minerals Yearbook*, U.S. Department of Interior, Bureau of Mines, Washington, DC, various years.
5. "Development of an Industrial SO_2 Emissions Inventory Baseline and 1995 Report to Congress," U.S. Environmental Protection Agency, Research Triangle Park, NC. December 1994.

Table 3-1. Total National Emissions of Carbon Monoxide, 1940 through 1998
(thousand short tons)

Source Category	1940	1950	1960	1970	1980	1990	1996	1998
FUEL COMB. ELEC. UTIL.	***4***	***110***	***110***	***237***	***322***	***363***	***391***	***417***
FUEL COMB. INDUSTRIAL	***435***	***549***	***661***	***770***	***750***	***879***	***1,155***	***1,115***
FUEL COMB. OTHER	***14,890***	***10,656***	***6,250***	***3,625***	***6,230***	***4,269***	***4,603***	***3,843***
Residential Wood	11,279	7,716	4,743	2,932	5,992	3,781	4,200	3,452
CHEMICAL & ALLIED PRODUCT MFG	***4,190***	***5,844***	***3,982***	***3,397***	***2,151***	***1,183***	***1,100***	***1,129***
Other Chemical Mfg	4,139	5,760	3,775	2,866	1,417	854	870	893
carbon black mfg	*4,139*	*5,760*	*3,775*	*2,866*	1,417	*798*	*841*	*863*
METALS PROCESSING	***2,750***	***2,910***	***2,866***	***3,644***	***2,246***	***2,640***	***1,429***	***1,495***
Nonferrous Metals Processing	36	118	326	652	842	436	442	446
Ferrous Metals Processing	2,714	2,792	2,540	2,991	1,404	2,163	944	1,006
basic oxygen furnace	*NA*	*NA*	*23*	*440*	*80*	*594*	*117*	*126*
PETROLEUM & RELATED INDUSTRIES	***221***	***2,651***	***3,086***	***2,179***	***1,723***	***333***	***356***	***368***
Oil & Gas Production	NA	NA	NA	NA	NA	38	26	27
Petroleum Refineries & Related Industries	221	2,651	3,086	2,168	1,723	291	322	334
fcc units	*210*	*2,528*	*2,810*	*1,820*	*1,680*	*284*	*311*	*322*
OTHER INDUSTRIAL PROCESSES	***114***	***231***	***342***	***620***	***830***	***537***	***600***	***632***
Wood, Pulp & Paper, & Publishing Products	110	220	331	610	798	473	391	416
sulfate pulping: rec. furnace/evaporator	*NA*	*NA*	*NA*	*NA*	*NA*	*370*	*305*	*325*
SOLVENT UTILIZATION	***NA***	***NA***	***NA***	***NA***	***NA***	***5***	***2***	***2***
STORAGE & TRANSPORT	***NA***	***NA***	***NA***	***NA***	***NA***	***76***	***78***	***80***
WASTE DISPOSAL & RECYCLING	***3,630***	***4,717***	***5,597***	***7,059***	***2,300***	***1,079***	***1,127***	***1,154***
Incineration	2,202	2,711	2,703	2,979	1,246	372	404	413
residential	*716*	*824*	*972*	*1,107*	*945*	*294*	*330*	*336*
Open Burning	1,428	2,006	2,894	4,080	1,054	706	717	735
residential	*NA*	*NA*	*NA*	*NA*	*NA*	*509*	*515*	*524*
ON-ROAD VEHICLES	***30,121***	***45,196***	***64,266***	***88,034***	***78,049***	***57,848***	***53,262***	***50,386***
Light-Duty Gas Vehicles & Motorcycles	22,237	31,493	47,679	64,031	53,561	37,407	28,732	27,039
light-duty gas vehicles	*22,232*	*31,472*	*47,655*	*63,846*	*53,342*	*37,198*	*28,543*	*26,848*
Light-Duty Gas Trucks	3,752	6,110	7,791	16,570	16,137	13,816	19,271	18,726
light-duty gas trucks 1	*2,694*	*4,396*	*5,591*	*10,102*	10,395	*8,415*	*11,060*	*10,826*
light-duty gas trucks 2	*1,058*	*1,714*	*2,200*	*6,468*	5,742	*5,402*	*8,211*	*7,900*
Heavy-Duty Gas Vehicles	4,132	7,537	8,557	6,712	7,189	5,360	3,766	3,067
Diesels	NA	54	239	721	1,161	1,265	1,493	1,554
heavy-duty diesel vehicles	*NA*	*54*	*239*	*721*	*1,139*	*1,229*	*1,453*	*1,514*
NON-ROAD ENGINES AND VEHICLES	***8,051***	***11,610***	***11,575***	***11,970***	***14,489***	***18,191***	***20,232***	***19,914***
Non-Road Gasoline	3,777	7,331	8,753	10,946	12,760	15,394	17,074	16,812
industrial	*780*	*1,558*	*1,379*	*535*	*709*	*723*	*592*	*563*
lawn & garden	*NA*	*NA*	*NA*	*5,899*	*6,764*	*8,237*	*9,305*	*9,024*
light commercial	*NA*	*NA*	*NA*	*1,905*	*2,095*	*2,877*	*3,514*	*3,566*
recreational marine vessels	*60*	*120*	*518*	*1,763*	*1,990*	*2,117*	*2,142*	*2,156*
Non-Road Diesel	32	53	65	430	829	1,098	1,282	1,180
construction	*20*	*43*	*40*	*254*	*479*	*662*	*794*	*728*
farm	*12*	*10*	*17*	*16*	*174*	*166*	*176*	*163*
Aircraft	4	934	1,764	506	743	904	949	955
Railroads	4,083	3,076	332	65	96	121	112	115
MISCELLANEOUS	***29,210***	***18,135***	***11,010***	***7,909***	***8,344***	***11,122***	***11,144***	***8,920***
Other Combustion	29,210	18,135	11,010	7,909	8,344	11,122	11,144	8,919
TOTAL ALL SOURCES	**93,616**	**102,609**	**109,745**	**129,444**	**117,434**	**98,523**	**95,480**	**89,455**

Note(s): NA = not available. For several source categories, emissions either prior to or beginning with 1985 are not available at the more detailed level but are contained in the more aggregate estimate.
"Other" categories may contain emissions that could not be accurately allocated to specific source categories.
In order to convert emissions to gigagrams (thousand metric tons), multiply the above values by 0.9072.

Table 3-2. Total National Emissions of Nitrogen Oxides, 1940 through 1998
(thousand short tons)

Source Category	1940	1950	1960	1970	1980	1990	1996	1998
FUEL COMB. ELEC. UTIL.	***660***	***1,316***	***2,536***	***4,900***	***7,024***	***6,663***	***6,057***	***6,103***
Coal	467	1,118	2,038	3,888	6,123	5,642	5,542	5,395
bituminous	*255*	*584*	*1,154*	*2,112*	*3,439*	*4,532*	*3,748*	*3,622*
Oil	193	198	498	1,012	901	221	103	208
residual	*6*	*23*	*8*	*40*	*39*	*207*	*101*	*206*
distillate	*187*	*175*	*490*	*972*	*862*	*14*	*2*	*2*
Gas	NA	NA	NA	NA	NA	565	265	344
natural	*NA*	*NA*	*NA*	*NA*	*NA*	*565*	*264*	*342*
FUEL COMB. INDUSTRIAL	***2,543***	***3,192***	***4,075***	***4,325***	***3,555***	***3,035***	***3,072***	***2,969***
Coal	2,012	1,076	782	771	444	585	567	548
Oil	122	237	239	332	286	265	231	216
Gas	365	1,756	2,954	3,060	2,619	1,182	1,184	1,154
natural	*337*	*1,692*	*2,846*	*3,053*	*2,469*	*967*	*978*	*943*
Internal Combustion	NA	NA	NA	NA	NA	874	967	932
FUEL COMB. OTHER	***529***	***647***	***760***	***836***	***741***	***1,196***	***1,224***	***1,117***
Commercial/Institutional Gas	7	18	55	120	131	200	238	234
Residential Other	177	227	362	439	356	780	783	700
natural gas	*20*	*50*	*148*	*242*	*238*	*449*	*481*	*410*
CHEMICAL & ALLIED PRODUCT MFG	***6***	***63***	***110***	***271***	***213***	***168***	***146***	***152***
METALS PROCESSING	***4***	***110***	***110***	***77***	***65***	***97***	***83***	***88***
PETROLEUM & RELATED INDUSTRIES	***105***	***110***	***220***	***240***	***72***	***153***	***134***	***138***
OTHER INDUSTRIAL PROCESSES	***107***	***93***	***131***	***187***	***205***	***378***	***386***	***408***
Mineral Products	105	89	123	169	181	270	286	303
cement mfg	*32*	*55*	*78*	*97*	*98*	*151*	*172*	*182*
SOLVENT UTILIZATION	***NA***	***NA***	***NA***	***NA***	***NA***	***1***	***2***	***2***
STORAGE & TRANSPORT	***NA***	***NA***	***NA***	***NA***	***NA***	***3***	***7***	***7***
WASTE DISPOSAL & RECYCLING	***110***	***215***	***331***	***440***	***111***	***91***	***95***	***97***
ON-ROAD VEHICLES	***1,330***	***2,143***	***3,982***	***7,390***	***8,621***	***7,089***	***7,848***	***7,765***
Light-Duty Gas Vehicles & Motorcycles	970	1,415	2,607	4,158	4,421	3,220	2,979	2,849
light-duty gas vehicles	*970*	*1,415*	*2,606*	*4,156*	*4,416*	*3,208*	*2,967*	*2,837*
Light-Duty Gas Trucks	204	339	525	1,278	1,408	1,256	1,950	1,917
light-duty gas trucks 1	*132*	*219*	*339*	*725*	*864*	*784*	*1,156*	*1,132*
light-duty gas trucks 2	*73*	*120*	*186*	*553*	*544*	*472*	*794*	*785*
Heavy-Duty Gas Vehicles	155	296	363	278	300	326	329	323
Diesels	NA	93	487	1,676	2,493	2,287	2,591	2,676
heavy-duty diesel vehicles	*NA*	*93*	*487*	*1,676*	*2,463*	*2,240*	*2,544*	*2,630*
NON-ROAD ENGINES AND VEHICLES	***991***	***1,538***	***1,443***	***1,931***	***3,529***	***4,804***	***5,167***	***5,280***
Non-Road Gasoline	122	249	312	85	101	120	132	159
Non-Road Diesel	103	187	247	1,109	2,125	2,513	2,786	2,809
construction	*70*	*158*	*157*	*436*	*843*	*1,102*	*1,218*	*1,230*
farm	*33*	*29*	*50*	*350*	*926*	*898*	*1,001*	*999*
Aircraft	NA	2	4	72	106	158	167	168
Marine Vessels	109	108	108	171	467	943	985	1,008
Railroads	657	992	772	495	731	929	922	947
MISCELLANEOUS	***990***	***665***	***441***	***330***	***248***	***369***	***452***	***328***
TOTAL ALL SOURCES	**7,374**	**10,093**	**14,140**	**20,928**	**24,384**	**24,049**	**24,676**	**24,454**

Note(s): NA = not available. For several source categories, emissions either prior to or beginning with 1985 are not available at the more detailed level but are contained in the more aggregate estimate.
"Other" categories may contain emissions that could not be accurately allocated to specific source categories.
In order to convert emissions to gigagrams (thousand metric tons), multiply the above values by 0.9072.

Table 3-3. Total National Emissions of Volatile Organic Compounds, 1940 through 1998 (thousand short tons)

Source Category	1940	1950	1960	1970	1980	1990	1996	1998
FUEL COMB. ELEC. UTIL.	***2***	***9***	***9***	***30***	***45***	***47***	***49***	***54***
FUEL COMB. INDUSTRIAL	***108***	***98***	***106***	***150***	***157***	***182***	***166***	***161***
FUEL COMB. OTHER	***1,867***	***1,336***	***768***	***541***	***848***	***776***	***821***	***678***
Residential Wood	1,410	970	563	460	809	718	759	620
CHEMICAL & ALLIED PRODUCT MFG	***884***	***1,324***	***991***	***1,341***	***1,595***	***634***	***388***	***396***
METALS PROCESSING	***325***	***442***	***342***	***394***	***273***	***122***	***72***	***75***
PETROLEUM & RELATED INDUSTRIES	***571***	***548***	***1,034***	***1,194***	***1,440***	***612***	***488***	***496***
OTHER INDUSTRIAL PROCESSES	***130***	***184***	***202***	***270***	***237***	***401***	***428***	***450***
SOLVENT UTILIZATION	***1,971***	***3,679***	***4,403***	***7,174***	***6,584***	***5,750***	***5,506***	***5,278***
Degreasing	168	592	438	707	513	744	606	457
Graphic Arts	114	310	199	319	373	274	296	311
Dry Cleaning	42	153	126	263	320	215	157	169
petroleum solvent	*NA*	*NA*	*NA*	*NA*	*NA*	*104*	*92*	*99*
Surface Coating	1,058	2,187	2,128	3,570	3,685	2,523	2,389	2,224
industrial adhesives	*14*	*41*	*29*	*52*	*55*	*390*	*356*	*160*
architectural	*284*	*NA*	*412*	*442*	*477*	*495*	*484*	*491*
Nonindustrial	490	NA	1,189	1,674	1,002	1,900	1,957	2,012
cutback asphalt	*328*	*NA*	*789*	*1,045*	*323*	*199*	*135*	*144*
pesticide application	*73*	*NA*	*193*	*241*	*241*	*258*	*386*	*405*
adhesives	*NA*	*NA*	*NA*	*NA*	*NA*	*361*	*307*	*313*
consumer solvents	*NA*	*NA*	*NA*	*NA*	*NA*	*1,083*	*1,081*	*1,099*
STORAGE & TRANSPORT	***639***	***1,218***	***1,762***	***1,954***	***1,975***	***1,495***	***1,286***	***1,324***
Bulk Terminals & Plants	185	361	528	599	517	359	211	217
area source: gasoline	*158*	*307*	*449*	*509*	*440*	*282*	*163*	*167*
Petroleum & Petroleum Product Storage	148	218	304	300	306	157	172	178
Petroleum & Petroleum Product Transport	57	100	115	92	61	151	118	122
Service Stations: Stage I	117	251	365	416	461	300	312	320
Service Stations: Stage II	130	283	437	521	583	433	397	409
WASTE DISPOSAL & RECYCLING	***990***	***1,104***	***1,546***	***1,984***	***758***	***986***	***423***	***433***
ON-ROAD VEHICLES	***4,817***	***7,251***	***10,506***	***12,972***	***8,979***	***6,313***	***5,490***	***5,325***
Light-Duty Gas Vehicles & Motorcycles	3,647	5,220	8,058	9,193	5,907	3,947	2,875	2,832
light-duty gas vehicles	*3,646*	*5,214*	*8,050*	*9,133*	*5,843*	*3,885*	*2,839*	*2,793*
Light-Duty Gas Trucks	672	1,101	1,433	2,770	2,059	1,622	2,060	2,015
Heavy-Duty Gas Vehicles	498	908	926	743	611	432	293	257
Diesels	NA	22	89	266	402	312	263	222
NON-ROAD ENGINES AND VEHICLES	***778***	***1,213***	***1,215***	***1,878***	***2,312***	***2,545***	***2,664***	***2,461***
Non-Road Gasoline	208	423	526	1,564	1,787	1,889	1,982	1,794
lawn & garden	*NA*	*NA*	*NA*	*511*	*583*	*700*	*771*	*638*
recreational marine vessels	*16*	*32*	*124*	*736*	*830*	*784*	*777*	*780*
Non-Road Diesel	12	20	23	187	327	390	422	405
construction	*6*	*15*	*13*	*94*	*135*	*181*	*206*	*199*
farm	*6*	*5*	*8*	*39*	*138*	*126*	*120*	*111*
Aircraft	3	110	220	97	146	180	177	177
NATURAL SOURCES	***NA***	***NA***	***NA***	***NA***	***NA***	***14***	***14***	***14***
MISCELLANEOUS	***4,079***	***2,530***	***1,573***	***1,101***	***1,134***	***1,059***	***940***	***772***
Other Combustion	4,079	2,530	1,573	1,101	1,134	1,049	891	721
TOTAL ALL SOURCES	**17,161**	**20,936**	**24,459**	**30,982**	**26,336**	**20,936**	**18,736**	**17,917**

Note(s): NA = not available. For several source categories, emissions either prior to or beginning with 1985 are not available at the more detailed level but are contained in the more aggregate estimate.
"Other" categories may contain emissions that could not be accurately allocated to specific source categories.
In order to convert emissions to gigagrams (thousand metric tons), multiply the above values by 0.9072.

Table 3-4. Total National Emissions of Sulfur Dioxide, 1940 through 1998
(thousand short tons)

Source Category	1940	1950	1960	1970	1980	1990	1996	1998
FUEL COMB. ELEC. UTIL.	***2,427***	***4,515***	***9,263***	***17,398***	***17,469***	***15,909***	***12,631***	***13,217***
Coal	2,276	4,056	8,883	15,799	16,073	15,220	12,137	12,426
bituminous	*1,359*	*2,427*	*5,367*	*9,574*	*NA*	*13,371*	*8,931*	*9,368*
subbituminous	*668*	*1,196*	*2,642*	*4,716*	*NA*	*1,415*	*2,630*	*2,440*
anthracite & lignite	*249*	*433*	*873*	*1,509*	*NA*	*434*	*576*	*618*
Oil	151	459	380	1,598	1,395	639	436	730
residual	*146*	*453*	*375*	*1,578*	*NA*	*629*	*430*	*726*
FUEL COMB. INDUSTRIAL	***6,060***	***5,725***	***3,864***	***4,568***	***2,951***	***3,550***	***3,022***	***2,895***
Coal	5,188	4,423	2,703	3,129	1,527	1,914	1,465	1,415
bituminous	*3,473*	*2,945*	*1,858*	*2,171*	*1,058*	*1,050*	*1,031*	*1,000*
Oil	554	972	922	1,229	1,065	927	844	773
residual	*397*	*721*	*663*	*956*	*851*	*687*	*637*	*568*
distillate	*9*	*49*	*42*	*98*	*85*	*198*	*187*	*184*
Gas	145	180	189	140	299	543	556	558
FUEL COMB. OTHER	***3,642***	***3,964***	***2,319***	***1,490***	***971***	***831***	***667***	***609***
Commercial/Institutional Coal	695	1,212	154	109	110	212	177	194
Commercial/Institutional Oil	407	658	905	883	637	425	338	275
Residential Other	2,517	2,079	1,250	492	211	175	131	121
bituminous/subbituminous coal	*2,267*	*1,758*	*868*	*260*	*43*	*30*	*17*	*18*
CHEMICAL & ALLIED PRODUCT MFG	**215**	**427**	**447**	**591**	**280**	**297**	**291**	**299**
Inorganic Chemical Mfg	215	427	447	591	271	214	204	210
sulfur compounds	*215*	*427*	*447*	*591*	*271*	*211*	*202*	*208*
METALS PROCESSING	***3,309***	***3,747***	***3,986***	***4,775***	***1,842***	***726***	***429***	***444***
Nonferrous Metals Processing	2,760	3,092	3,322	4,060	1,279	517	283	288
copper	*2,292*	*2,369*	*2,772*	*3,507*	*1,080*	*323*	*114*	*119*
lead	*80*	*95*	*57*	*77*	*34*	*129*	*111*	*110*
Ferrous Metals Processing	550	655	664	715	562	186	128	139
PETROLEUM & RELATED INDUSTRIES	***224***	***340***	***676***	***881***	***734***	***430***	***337***	***345***
Oil & Gas Production	NA	14	114	111	157	122	95	96
natural gas	*NA*	*14*	*114*	*111*	*157*	*120*	*95*	*95*
Petroleum Refineries & Related Industries	224	326	562	770	577	304	234	241
fluid catalytic cracking units	*220*	*242*	*383*	*480*	*330*	*183*	*153*	*158*
OTHER INDUSTRIAL PROCESSES	***334***	***596***	***671***	***846***	***918***	***399***	***350***	***370***
Wood, Pulp & Paper, & Publishing Products	NA	43	114	169	223	116	102	108
Mineral Products	334	553	557	677	694	275	230	243
cement mfg	*318*	*522*	*524*	*618*	*630*	*181*	*147*	*156*
SOLVENT UTILIZATION	***NA***	***NA***	***NA***	***NA***	***NA***	***0***	***1***	***1***
STORAGE & TRANSPORT	***NA***	***NA***	***NA***	***NA***	***NA***	***7***	***3***	***3***
WASTE DISPOSAL & RECYCLING	***3***	***3***	***10***	***8***	***33***	***42***	***41***	***42***
ON-ROAD VEHICLES	***3***	***103***	***114***	***411***	***521***	***542***	***316***	***326***
Light-Duty Gas Vehicles & Motorcycles	NA	NA	NA	132	159	138	127	130
Diesels	NA	NA	NA	231	303	337	83	85
NON-ROAD ENGINES AND VEHICLES	***3,190***	***2,392***	***321***	***83***	***175***	***916***	***1,016***	***1,084***
Marine Vessels	215	215	105	43	117	251	237	261
Railroads	2,975	2,174	215	36	53	122	111	114
MISCELLANEOUS	***545***	***545***	***554***	***110***	***11***	***12***	***17***	***12***
Other Combustion	545	545	554	110	11	12	17	12
Fugitive Dust				NA	NA	0	0	0
TOTAL ALL SOURCES	**19,952**	**22,357**	**22,227**	**31,161**	**25,905**	**23,660**	**19,121**	**19,647**

Note(s): NA = not available. For several source categories, emissions either prior to or beginning with 1985 are not available at the more detailed level but are contained in the more aggregate estimate. Zero values represent less than 500 short tons/year.
"Other" categories may contain emissions that could not be accurately allocated to specific source categories.
The 1985 fuel combustion, electric utility category is based on the National Allowance Data Base Version 2.11, Acid Rain Division, U.S. EPA, released March 23, 1993. Allocations at the Tier 3 levels are approximations only and are based on the methodology described in section 6.0, paragraph 6.2.1.1.
In order to convert emissions to gigagrams (thousand metric tons), multiply the above values by 0.9072.

Table 3-5. Total National Emissions of Directly Emitted Particulate Matter (PM_{10}), 1940 through 1998 (thousand short tons)

Source Category	1940	1950	1960	1970	1980	1990	1996	1998
FUEL COMB. ELEC. UTIL.	***962***	***1,467***	***2,117***	***1,775***	***879***	***295***	***287***	***302***
Coal	954	1,439	2,092	1,680	796	265	264	273
bituminous	*573*	*865*	*1,288*	*1,041*	*483*	*188*	*195*	*200*
FUEL COMB. INDUSTRIAL	***708***	***604***	***331***	***641***	***679***	***270***	***255***	***245***
Coal	549	365	146	83	18	84	77	74
Other	120	160	103	441	571	87	77	74
FUEL COMB. OTHER	***2,338***	***1,674***	***1,113***	***455***	***887***	***631***	***632***	***544***
Residential Wood	1,716	1,128	850	384	818	501	503	411
CHEMICAL & ALLIED PRODUCT MFG	***330***	***455***	***309***	***235***	***148***	***77***	***63***	***65***
METALS PROCESSING	***1,208***	***1,027***	***1,026***	***1,316***	***622***	***214***	***164***	***171***
Nonferrous Metals Processing	588	346	375	593	130	50	35	37
copper	*217*	*105*	*122*	*343*	*32*	*14*	*7*	*7*
Ferrous Metals Processing	246	427	214	198	322	155	108	112
primary	*86*	*98*	*51*	*31*	*271*	*128*	*86*	*91*
PETROLEUM & RELATED INDUSTRIES	***366***	***412***	***689***	***286***	***138***	***55***	***32***	***32***
OTHER INDUSTRIAL PROCESSES	***3,996***	***6,954***	***7,211***	***5,832***	***1,846***	***583***	***327***	***339***
Agriculture, Food, & Kindred Products	784	696	691	485	402	73	61	61
country elevators	*299*	*307*	*343*	*257*	*258*	*9*	*6*	*6*
terminal elevators	*351*	*258*	*224*	*147*	*86*	*6*	*2*	*2*
Wood, Pulp & Paper, & Publishing Products	511	798	958	727	183	105	78	82
sulfate (kraft) pulping	*470*	*729*	*886*	*668*	*142*	*73*	*43*	*45*
Mineral Products	2,701	5,460	5,563	4,620	1,261	367	156	162
cement mfg	*1,363*	*1,998*	*2,014*	*1,731*	*417*	*190*	*21*	*22*
stone quarrying/processing	*482*	*663*	*1,039*	*957*	*421*	*54*	*24*	*24*
SOLVENT UTILIZATION	***NA***	***NA***	***NA***	***NA***	***NA***	***4***	***6***	***6***
STORAGE & TRANSPORT	***NA***	***NA***	***NA***	***NA***	***NA***	***102***	***90***	***94***
Bulk Materials Storage	NA	NA	NA	NA	NA	100	87	91
WASTE DISPOSAL & RECYCLING	***392***	***505***	***764***	***999***	***273***	***271***	***304***	***310***
Open Burning	220	333	544	770	198	206	211	215
residential	*220*	*333*	*544*	*770*	*198*	*195*	*194*	*197*
ON-ROAD VEHICLES	***210***	***314***	***554***	***443***	***397***	***336***	***282***	***257***
Diesels	NA	9	15	136	208	235	177	152
heavy-duty diesel vehicles	*NA*	*9*	*15*	*136*	*194*	*224*	*168*	*144*
NON-ROAD ENGINES AND VEHICLES	***2,480***	***1,788***	***201***	***220***	***398***	***489***	***457***	***461***
Non-Road Diesel	1	16	22	281	439	301	297	301
construction	*0*	*12*	*12*	*102*	*148*	*149*	*147*	*150*
farm	*0*	*4*	*7*	*140*	*239*	*78*	*72*	*69*
Railroads	2,464	1,742	110	25	37	53	27	27
NATURAL SOURCES	***NA***	***NA***	***NA***	***NA***	***NA***	***2,092***	***5,307***	***5,307***
*Geogenic - wind erosion**	*NA*	*NA*	*NA*	*NA*	*NA*	*2,092*	*5,307*	*5,307*
MISCELLANEOUS	***2,968***	***1,934***	***1,244***	***839***	***852***	***24,542***	***24,836***	***26,609***
Agriculture & Forestry	NA	NA	NA	NA	NA	5,292	4,905	4,970
*agricultural crops***	*NA*	*NA*	*NA*	*NA*	*NA*	*4,745*	*4,328*	*4,366*
*agricultural livestock***	*NA*	*NA*	*NA*	*NA*	*NA*	*547*	*577*	*603*
Other Combustion	2,968	1,934	1,244	839	852	1,181	1,254	1,018
Fugitive Dust	NA	NA	NA	NA	NA	18,069	18,675	20,619
*unpaved roads***	*NA*	*NA*	*NA*	*NA*	*NA*	*11,234*	*12,059*	*12,668*
*paved roads***	*NA*	*NA*	*NA*	*NA*	*NA*	*2,248*	*2,390*	*2,618*
*construction***				*NA*	*NA*	*4,249*	*3,578*	*4,545*
TOTAL ALL SOURCES	**15,957**	**17,133**	**15,558**	**13,042**	**7,119**	**29,962**	**33,041**	**34,741**

Note(s): NA = not available. For several source categories, emissions either prior to or beginning with 1985 are not available at the more detailed level but are contained in the more aggregate estimate. Zero values represent less than 500 short tons/year.
Categories displayed below Tier 1 do not sum to Tier 1 totals because they are intended to show major contributors.
In order to convert emissions to gigagrams (thousand metric tons), multiply the above values by 0.9072.

* Although geogenic wind erosion emissions are included in this summary table, it is very difficult to interpret annual estimates of PM emissions from this source category in a meaningful way, owing to the highly episodic nature of the events that contribute to these emissions.

** These are the main source categories of PM crustal material emissions. A report by the Desert Research Institute found that about 75% of these emissions are within 2 m of the ground at the point they are measured. Thus, most of them are likely to be removed or deposited within a few km of their release, depending on atmospheric turbulence, temperature, soil moisture, availability of horizontal and vertical surfaces for impaction and initial suspension energy. This is consistent with the generally small amount of crustal materials found on speciated ambient samples. (See reference 6 in Chapter 2.)

Table 3-6. Total National Emissions of Directly Emitted Particulate Matter ($PM_{2.5}$), 1990 through 1998 (thousand short tons)

Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998
FUEL COMB. ELEC. UTIL.	***121***	***105***	***106***	***112***	***108***	***107***	***156***	***160***	***165***
Coal	97	85	87	90	86	86	133	135	138
bituminous	*59*	*53*	*53*	*57*	*54*	*52*	*88*	*89*	*91*
FUEL COMB. INDUSTRIAL	***177***	***151***	***159***	***172***	***183***	***203***	***166***	***161***	***160***
Other	73	58	59	69	60	59	62	60	60
FUEL COMB. OTHER	***611***	***638***	***662***	***568***	***550***	***589***	***537***	***466***	***466***
Residential Wood	501	535	558	464	446	484	433	358	357
CHEMICAL & ALLIED PRODUCT MFG	***47***	***43***	***45***	***41***	***49***	***42***	***38***	***39***	***39***
METALS PROCESSING	***157***	***197***	***198***	***125***	***125***	***134***	***108***	***113***	***112***
Ferrous Metals Processing	121	89	83	86	86	92	69	72	72
primary	*103*	*72*	*66*	*68*	*68*	*74*	*53*	*56*	*56*
PETROLEUM & RELATED INDUSTRIES	***27***	***24***	***24***	***22***	***22***	***22***	***18***	***18***	***18***
OTHER INDUSTRIAL PROCESSES	***284***	***264***	***259***	***260***	***256***	***256***	***178***	***184***	***187***
Wood, Pulp & Paper, & Publishing Products	77	61	59	59	57	60	54	56	57
Mineral Products	144	134	135	136	133	134	83	87	88
SOLVENT UTILIZATION	***4***	***4***	***5***	***6***	***6***	***5***	***5***	***5***	***5***
STORAGE & TRANSPORT	***42***	***42***	***50***	***46***	***43***	***42***	***31***	***32***	***32***
WASTE DISPOSAL & RECYCLING	***234***	***238***	***239***	***288***	***271***	***247***	***234***	***236***	***238***
Open Burning	187	190	192	195	196	197	186	188	190
residential	*177*	*179*	*181*	*183*	*184*	*185*	*176*	*177*	*179*
ON-ROAD VEHICLES	***275***	***286***	***280***	***257***	***256***	***231***	***221***	***211***	***197***
Diesels	212	221	216	192	190	169	157	147	134
hddv	*203*	*212*	*206*	*183*	*182*	*161*	*149*	*140*	*127*
NON-ROAD ENGINES AND VEHICLES	***432***	***432***	***433***	***427***	***424***	***403***	***410***	***411***	***413***
Non-Road Diesel	277	275	273	273	272	272	274	275	277
construction	*137*	*136*	*136*	*135*	*134*	*134*	*135*	*136*	*138*
farm	*71*	*71*	*70*	*69*	*68*	*67*	*66*	*65*	*63*
NATURAL SOURCES	***314***	***312***	***334***	***76***	***324***	***172***	***796***	***796***	***796***
Geogenic - wind erosion*	314	312	334	76	324	172	796	796	796
MISCELLANEOUS	***5,234***	***5,004***	***4,854***	***4,926***	***5,360***	***4,725***	***5,298***	***5,652***	***5,549***
Agriculture & Forestry	1,031	1,019	976	887	941	952	952	964	964
*agricultural crops***	*949*	*937*	*893*	*803*	*856*	*867*	*866*	*875*	*873*
*agricultural livestock***	*82*	*83*	*83*	*84*	*85*	*85*	*87*	*90*	*91*
Other Combustion	1,037	807	666	693	913	734	1,040	1,150	882
Fugitive Dust	3,166	3,178	3,213	3,346	3,506	3,038	3,304	3,535	3,701
*unpaved roads***	*1,687*	*1,684*	*1,642*	*1,718*	*1,709*	*1,559*	*1,819*	*1,892*	*1,912*
*paved roads***	*562*	*600*	*606*	*616*	*634*	*585*	*598*	*635*	*655*
*construction***	*850*	*818*	*892*	*930*	*1,049*	*777*	*750*	*857*	*968*
TOTAL ALL SOURCES	**7,958**	**7,739**	**7,648**	**7,327**	**7,975**	**7,179**	**8,194**	**8,483**	**8,379**

Note(s): NA = not available. Zero values represent less than 500 short tons/year.
Categories displayed below Tier 1 do not sum to Tier 1 totals because they are intended to show major contributors.
In order to convert emissions to gigagrams (thousand metric tons), multiply the above values by 0.9072.

* Although geogenic wind erosion emissions are included in this summary table, it is very difficult to interpret annual estimates of PM emissions from this source category in a meaningful way, owing to the highly episodic nature of the events that contribute to these emissions.

* These are the main source categories of PM crustal material emissions. A report by the Desert Research Institute found that about 75% of these emissions are within 2 m of the ground at the point they are measured. Thus, most of them are likely to be removed or deposited within a few km of their release, depending on atmospheric turbulence, temperature, soil moisture, initial suspension energy and availability of horizontal and vertical surfaces for impaction. This is consistent with the generally small amount of crustal materials found on speciated ambient samples. (See reference 6 in Chapter 2.)

For a complete understanding of $PM_{2.5}$ emissions, one should also consider the emissions of SO_2, NO_x, and NH_3. These gases react in the atmosphere to form ammonium sulfate and ammonium nitrate fine particles; also, some organic particles are formed from VOCs. These "secondary" fine particles (in contrast to the directly emitted particles from combustion and fugitive dust) can comprise as much as half the $PM_{2.5}$ measured in the United States.[7] Source apportionment studies exist to help elucidate the role of primary PM (reflected in the NET) and secondary PM.

Table 3-7. Total National Emissions of Lead, 1970 through 1998
(short tons)

Source Category	1970	1975	1980	1985	1990	1996	1998
FUEL COMB. ELEC. UTIL.	***327***	***230***	***129***	***64***	***64***	***61***	***68***
Coal	300	189	95	51	46	53	54
bituminous	*181*	*114*	*57*	*31*	*28*	*32*	*33*
Oil	28	41	34	13	18	8	14
FUEL COMB. INDUSTRIAL	***237***	***75***	***60***	***30***	***18***	***16***	***19***
Coal	218	60	45	22	14	13	13
bituminous	*146*	*40*	*31*	*15*	*10*	*9*	*9*
Oil	19	16	14	8	3	3	5
FUEL COMB. OTHER	***10,052***	***10,042***	***4,111***	***421***	***418***	***415***	***416***
Misc. Fuel Comb. (Except Residential)	10,000	10,000	4,080	400	400	400	400
CHEMICAL & ALLIED PRODUCT MFG	***103***	***120***	***104***	***118***	***136***	***167***	***175***
Inorganic Chemical Mfg	103	120	104	118	136	167	175
lead oxide and pigments	*103*	*120*	*104*	*118*	*136*	*167*	*175*
METALS PROCESSING	***24,224***	***9,923***	***3,026***	***2,097***	***2,170***	***2,055***	***2,098***
Nonferrous Metals Processing	15,869	7,192	1,826	1,376	1,409	1,333	1,371
primary lead production	*12,134*	*5,640*	*1,075*	*874*	*728*	*588*	*628*
primary copper production	*242*	*171*	*20*	*19*	*19*	*22*	*23*
primary zinc production	*1,019*	*224*	*24*	*16*	*9*	*13*	*13*
secondary lead production	*1,894*	*821*	*481*	*288*	*449*	*514*	*505*
secondary copper production	*374*	*200*	*116*	*70*	*75*	*76*	*83*
lead battery manufacture	*41*	*49*	*50*	*65*	*78*	*103*	*117*
lead cable coating	*127*	*55*	*37*	*43*	*50*	*16*	*1*
Ferrous Metals Processing	7,395	2,196	911	577	576	529	542
coke manufacturing	*11*	*8*	*6*	*3*	*4*	*0*	*0*
ferroalloy production	*219*	*104*	*13*	*7*	*18*	*8*	*4*
iron production	*266*	*93*	*38*	*21*	*18*	*18*	*19*
steel production	*3,125*	*1,082*	*481*	*209*	*138*	*160*	*173*
gray iron production	*3,773*	*910*	*373*	*336*	*397*	*343*	*345*
Metals Processing NEC	960	535	289	144	185	193	186
metal mining	*353*	*268*	*207*	*141*	*184*	*192*	*186*
OTHER INDUSTRIAL PROCESSES	***2,028***	***1,337***	***808***	***316***	***169***	***51***	***54***
Mineral Products	540	217	93	43	26	29	31
cement manufacturing	*540*	*217*	*93*	*43*	*26*	*29*	*31*
Miscellaneous Industrial Processes	1,488	1,120	715	273	143	22	23
WASTE DISPOSAL & RECYCLING	***2,200***	***1,595***	***1,210***	***871***	***804***	***609***	***620***
Incineration	2,200	1,595	1,210	871	804	609	620
municipal waste	*581*	*396*	*161*	*79*	*67*	*76*	*75*
other	*1,619*	*1,199*	*1,049*	*792*	*738*	*534*	*546*
ON-ROAD VEHICLES	***171,961***	***130,206***	***60,501***	***18,052***	***421***	***19***	***19***
Light-Duty Gas Vehicles & Motorcycles	142,918	106,868	47,184	13,637	314	12	12
Light-Duty Gas Trucks	22,683	19,440	11,671	4,061	100	7	7
Heavy-Duty Gas Vehicles	6,361	3,898	1,646	354	7	0	0
NON-ROAD ENGINES AND VEHICLES	***9,737***	***6,130***	***4,205***	***921***	***776***	***505***	***503***
Non-Road Gasoline	8,340	5,012	3,320	229	158	0	0
Aircraft	1,397	1,118	885	692	619	505	503
TOTAL ALL SOURCES	**220,869**	**159,659**	**74,153**	**22,890**	**4,975**	**3,899**	**3,973**

Note(s): NA = not available. For several source categories, emissions either prior to or beginning with 1985 are not available at the more detailed level but are contained in the more aggregate estimate. Zero values represent less than 500 short tons/year. Categories displayed below Tier 1 do not sum to Tier 1 totals because they are intended to show major contributors. In order to convert emissions to gigagrams (thousand metric tons), multiply the above values by 0.9072.

Table 3-8. Total National Emissions of Ammonia, 1990 through 1998
(thousand short tons)

Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998
FUEL COMB. ELEC. UTIL.	***0***	***0***	***0***	***0***	***0***	***0***	***6***	***7***	***8***
FUEL COMB. INDUSTRIAL	***17***	***17***	***17***	***18***	***18***	***18***	***49***	***48***	***47***
FUEL COMB. OTHER	***8***	***8***	***8***	***8***	***8***	***8***	***7***	***7***	***6***
CHEMICAL & ALLIED PRODUCT MFG	***183***	***183***	***183***	***183***	***183***	***183***	***158***	***160***	***165***
METALS PROCESSING	***6***	***6***	***6***	***6***	***6***	***6***	***5***	***5***	***5***
PETROLEUM & RELATED INDUSTRIES	***43***	***43***	***43***	***43***	***43***	***43***	***34***	***35***	***35***
OTHER INDUSTRIAL PROCESSES	***38***	***38***	***39***	***39***	***40***	***40***	***43***	***44***	***44***
SOLVENT UTILIZATION	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
STORAGE & TRANSPORT	***0***	***0***	***0***	***0***	***0***	***0***	***1***	***1***	***1***
WASTE DISPOSAL & RECYCLING	***82***	***86***	***89***	***93***	***93***	***93***	***84***	***84***	***86***
ON-ROAD VEHICLES	***192***	***205***	***217***	***227***	***239***	***259***	***231***	***240***	***250***
NON-ROAD ENGINES AND VEHICLES	***6***	***7***	***7***	***7***	***7***	***7***	***9***	***10***	***10***
NATURAL SOURCES	***30***	***29***	***28***	***29***	***30***	***31***	***32***	***33***	***34***
Biogenic	30	29	28	29	30	31	32	33	34
MISCELLANEOUS	***3,727***	***3,770***	***3,814***	***3,869***	***3,924***	***3,979***	***4,113***	***4,163***	***4,244***
Agriculture & Forestry	3,727	3,770	3,814	3,869	3,924	3,979	4,113	4,163	4,244
livestock agriculture	*3,307*	*3,324*	*3,341*	*3,370*	*3,399*	*3,427*	*3,456*	*3,485*	*3,520*
fertilizer application	*420*	*446*	*473*	*499*	*525*	*551*	*657*	*678*	*724*
TOTAL ALL SOURCES	**4,331**	**4,390**	**4,449**	**4,521**	**4,589**	**4,665**	**4,772**	**4,837**	**4,935**

Note(s): NA = not available. Zero values represent less than 500 short tons/year.
Categories displayed below Tier 1 do not sum to Tier 1 totals because they are intended to show major contributors.
In order to convert emissions to gigagrams (thousand metric tons), multiply the above values by 0.9072.

Table 3-9. Carbon Monoxide Federal Emission Standards, 1970 to 1991

	Emission Limit (grams of CO per mile)	
Model year	**Light-duty Vehicles**	**Light-duty Trucks (0 to 6,000 lbs.)**
1970-1971	23	
1972-1974	39	39
1975-1979	15	20[1]
1980-1991	3.4[2]	18[3],10[4]

Note(s):
[1] Standard applies for 1975-1978 model years.
[2] Certain vehicles were subject to a less stringent requirement of 7.0 grams per mile from model years 1980-1984.
[3] Standard applies for 1979-1983 model years.
[4] Standard applies for 1984-1991 model years.

The first vehicle standards were implemented by the Federal government in 1968 and were concentration based (ppm of exhaust for hydrocarbons and CO). The first mass based standards (g/mile) were in 1972.

Table 3-10. Nitrogen Oxide and Volatile Organic Compound Federal Emission Limits for Light-Duty Vehicles, 1972 to 1991

	Emission Limit (grams per mile)	
Model Year	**NO_x**	**VOC[1]**
1972-1974	3.0[2]	3.4
1975-1979	3.1[3], 2.0[4]	1.5
1980-1991	1.0[5]	0.41

Note(s):
[1] These are exhaust emission standards for VOC.
[2] Standard applies for 1973-1974 model years.
[3] Standard applies for 1975-1976 model years.
[4] Standard applies for 1977-1980 model years.
[5] Standard applies for 1981-1991 model years.

The first vehicle standards were implemented by the Federal government in 1968 and were concentration based (ppm of exhaust for hydrocarbons and CO). The first mass based standards (g/mile) were in 1972.

Table 3-11. Nitrogen Oxide and Volatile Organic Compound Federal Emission Limits for Light-Duty Trucks, 1972 to 1991

	Emission Limit (grams per mile)	
Model Year	**NO_x**	**VOC[1]**
1972-1974	3.0[2]	3.4
1975-1978	3.1[3]	2.0
1979-1984	2.3[4]	1.7
1985-1991	1.2[5,6]	0.8

Note(s):
[1] These are exhaust emission standards for VOC.
[2] Standard applies for 1973-1974 model years.
[3] Standard applies for 1975-1978 model years.
[4] Standard applies for 1979-1987 model years.
[5] Standard applies for 1988-1993 model years.
[6] Light-duty trucks with a loaded-vehicle weight more than 3,750 pounds are subject to a 1.7 grams per mile standard for these model years.

The first vehicle standards were implemented by the Federal government in 1968 and were concentration based (ppm of exhaust for hydrocarbons and CO). The first mass based standards (g/mile) were in 1972.

Table 3-12. Federal Test Procedure Exhaust Emissions Standards and Schedule for Light-Duty Vehicles and Light-Duty Trucks, 1992 to 1998

			Vehicle Useful Life (grams/mile)									
			5 Years/50,100 Miles					10 Years/100,100 Miles[1]				
Vehicle Type	**Emission Category**	**Year[2]**	**THC[3]**	**NMHC[4]**	**CO**	**NO_x**	**PM_{10}**	**THC**	**NMHC**	**CO**	**NO_x**	**PM_{10}**
LDV	Tier 0	1992	0.41	0.34	3.4	1.0	0.20					
LDV	Tier I	1996	0.41	0.25	3.4	0.4	0.08		0.31	4.2	0.6	0.10
LDGT1a[5]	Tier 0	1992						0.80	0.67	10	1.2	0.26
LDGT1a	Tier I	1996		0.25	3.4	0.4	0.08	0.80	0.31	4.2	0.6	0.10
LDGT1b[6]	Tier 0	1992						0.80	0.67	10	1.7	0.13
LDGT1b	Tier I	1996		0.32	4.4	0.7	0.08	0.80	0.40	5.5	0.97	0.10
LDGT2a[7]	Tier 0	1992						0.80	0.67	10	1.7	0.26
LDGT2a	Tier I	1997		0.32	4.4	0.7		0.80	0.46	6.4	1.0	0.10
LDGT2b[8]	Tier 0	1992						0.80	0.67	10	1.7	0.13
LDGT2b	Tier I	1997		0.39	5.0	1.1		0.80	0.56	7.3	1.53	0.12

Notes:
[1] LDGT2: 11 years/120,000 miles
[2] Year Standard is 100 percent of vehicles affected
[3] Total hydrocarbons
[4] Nonmethane Hydrocarbon
[5] Any light light-duty truck up through 3,750 lbs loaded vehicle weight.
[6] Any light light-duty truck greater than 3,750 lbs loaded vehicle weight.
[7] Any heavy light-duty truck up through 5,750 lbs adjusted loaded vehicle weight.
[8] Any heavy light-duty truck greater than 5,750 lbs adjusted loaded vehicle weight.

The first vehicle standards were implemented by the Federal government in 1968 and were concentration based (ppm of exhaust for hydrocarbons and CO). The first mass based standards (g/mile) were in 1972.

Source: U.S. EPA Office of Mobile Sources, EPA-420-B-98-001

Table 3-13. Total National Emissions by Pollutant and Year

Year	CO	NO_x	VOC	SO_2	PM_{10}	$PM_{2.5}$	Pb	NH_3
1940	93,616	7,374	17,161	19,952	15,957			
1941	91,657	8,262	17,235	22,857	16,074			
1942	92,449	8,389	16,358	24,541	16,192			
1943	93,241	8,972	16,323	26,846	16,309			
1944	94,033	9,455	16,539	27,092	16,427			
1945	94,825	9,548	17,308	26,007	16,545			
1946	95,617	9,993	20,549	23,297	16,663			
1947	96,409	10,470	19,507	26,298	16,780			
1948	97,202	9,985	19,349	24,284	16,898			
1949	97,993	10,247	19,720	20,801	17,016			
1950	102,609	10,093	20,936	22,357	17,133			
1951	99,285	10,535	20,398	21,477	16,976			
1952	99,784	11,056	20,208	20,826	16,818			
1953	100,283	11,104	21,258	20,920	16,661			
1954	100,782	11,663	21,232	20,181	16,503			
1955	101,281	11,563	21,973	20,883	16,345			
1956	101,780	11,867	22,902	21,039	16,188			
1957	102,279	12,248	22,784	21,272	16,031			
1958	102,778	13,012	21,846	22,634	15,873			
1959	103,278	13,486	22,703	22,654	15,715			
1960	109,745	14,140	24,459	22,227	15,558			
1961	106,207	13,809	24,584	22,142	15,286			
1962	108,637	14,408	25,036	22,955	15,014			
1963	111,067	15,100	27,062	24,133	14,742			
1964	113,498	15,871	26,948	25,301	14,470			
1965	115,928	16,579	27,630	26,750	14,198			
1966	118,358	17,390	27,827	28,849	13,926			
1967	120,788	17,635	28,209	28,493	13,654			
1968	123,219	18,372	26,568	30,263	13,382			
1969	125,649	18,847	26,764	30,961	13,110			
1970	129,444	20,928	30,982	31,161	13,042		220,869	
1971	129,491	21,559	30,039	29,686	11,335		243,415	
1972	128,779	22,740	30,297	30,390	10,734		255,555	
1973	125,935	23,529	29,873	31,754	10,237		223,686	
1974	119,978	22,915	28,042	30,032	9,636		178,693	
1975	116,757	22,632	26,079	28,011	7,671		159,659	
1976	120,963	24,051	26,991	28,435	7,906		165,349	
1977	120,868	24,808	27,426	28,623	7,739		152,467	
1978	122,150	25,070	27,655	26,877	7,865		137,964	
1979	118,475	24,716	27,161	26,941	7,571		116,786	
1980	117,434	24,384	26,336	25,905	7,119		74,153	
1981	114,396	24,211	24,956	24,612	6,605		58,884	
1982	112,260	23,785	23,866	23,319	5,274		57,666	
1983	117,675	23,639	25,078	22,807	6,021		49,232	
1984	116,533	24,322	26,015	23,816	6,281		42,217	
1985	117,013	23,198	24,428	23,658	45,445		22,890	
1986	111,688	22,808	23,617	22,892	51,137		7,296	
1987	110,798	23,068	23,470	22,675	42,533		6,840	
1988	118,729	24,124	24,306	23,135	61,072		7,053	
1989	106,439	23,893	22,513	23,293	53,064		5,468	

Table 3-13 (continued)

Year	CO	NO_x	VOC	SO_2	PM_{10}	$PM_{2.5}$	Pb	NH_3
1990	98,523	24,049	20,936	23,660	29,962	7,958	4,975	4,331
1991	100,872	24,249	21,102	23,041	29,560	7,739	4,169	4,390
1992	97,630	24,596	20,659	22,806	29,472	7,648	3,810	4,449
1993	98,160	24,961	20,868	22,466	28,006	7,327	3,916	4,521
1994	102,643	25,372	21,535	21,870	30,913	7,975	4,047	4,589
1995	93,353	24,921	20,817	19,181	27,070	7,179	3,929	4,665
1996	95,479	24,676	18,736	19,121	33,041	8,194	3,899	4,772
1997	94,410	24,824	18,876	19,622	34,226	8,483	3,952	4,837
1998	89,454	24,454	17,917	19,647	34,741	8,379	3,973	4,935

Figure 3-1. Trend in Gross Domestic Product, Population, Vehicle Miles Traveled, Total Fuel Consumption, combined VOLATILE ORGANIC COMPOUND and NITROGEN OXIDES Emissions, and SULFUR DIOXIDE Emissions, 1970 to 1998

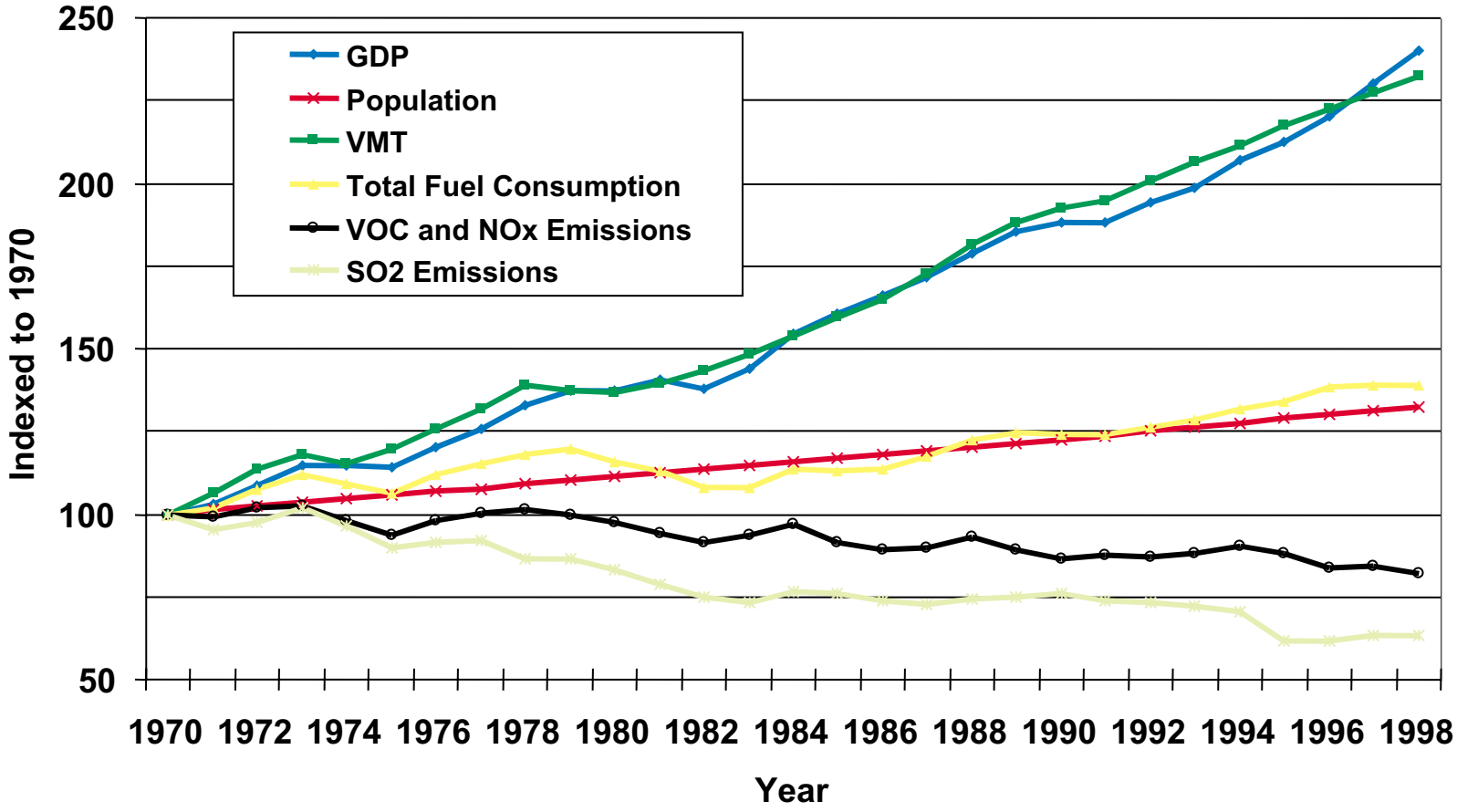
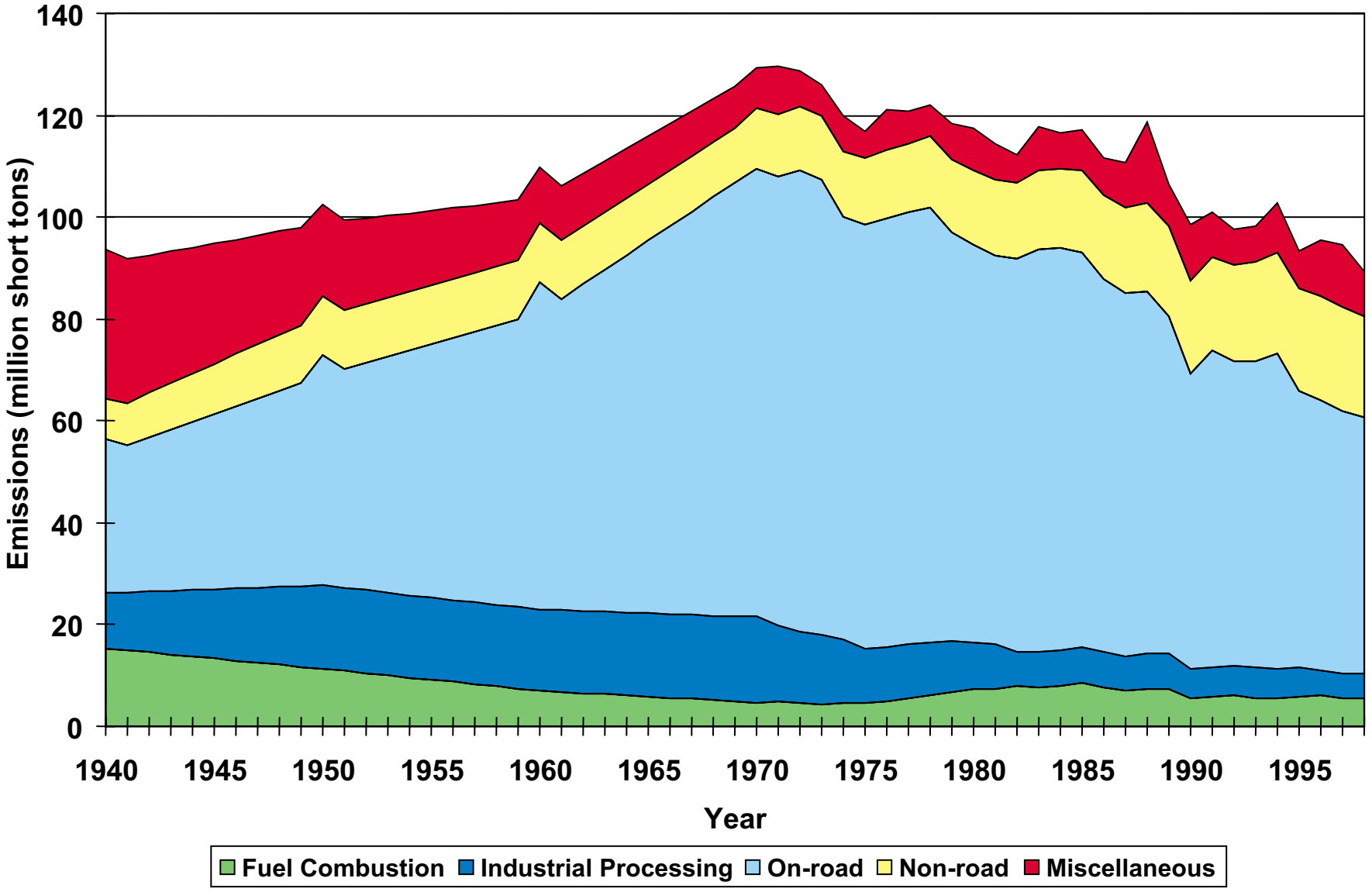
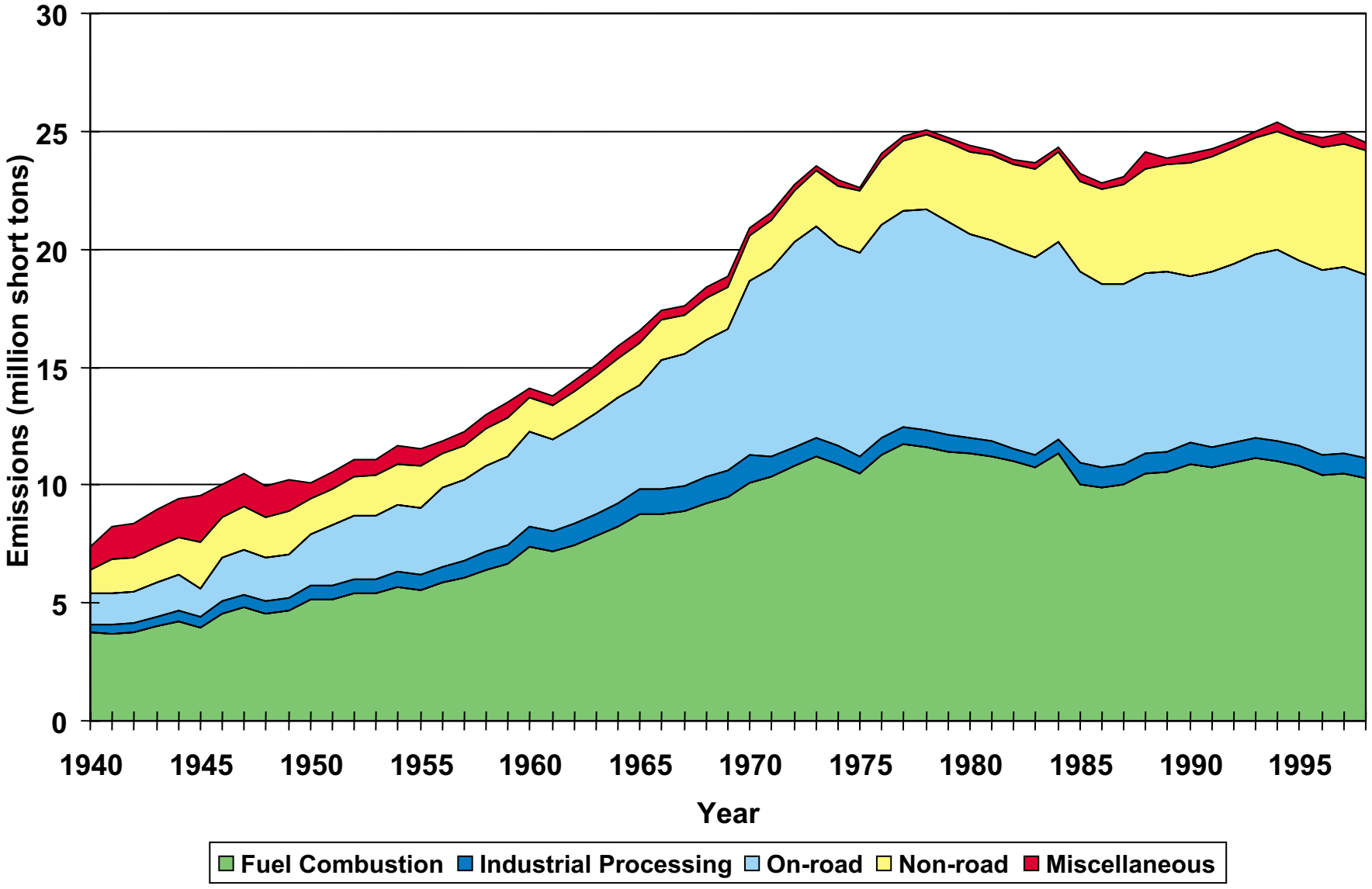


Figure 3-2. Trend in CARBON MONOXIDE Emissions, 1940 to 1998



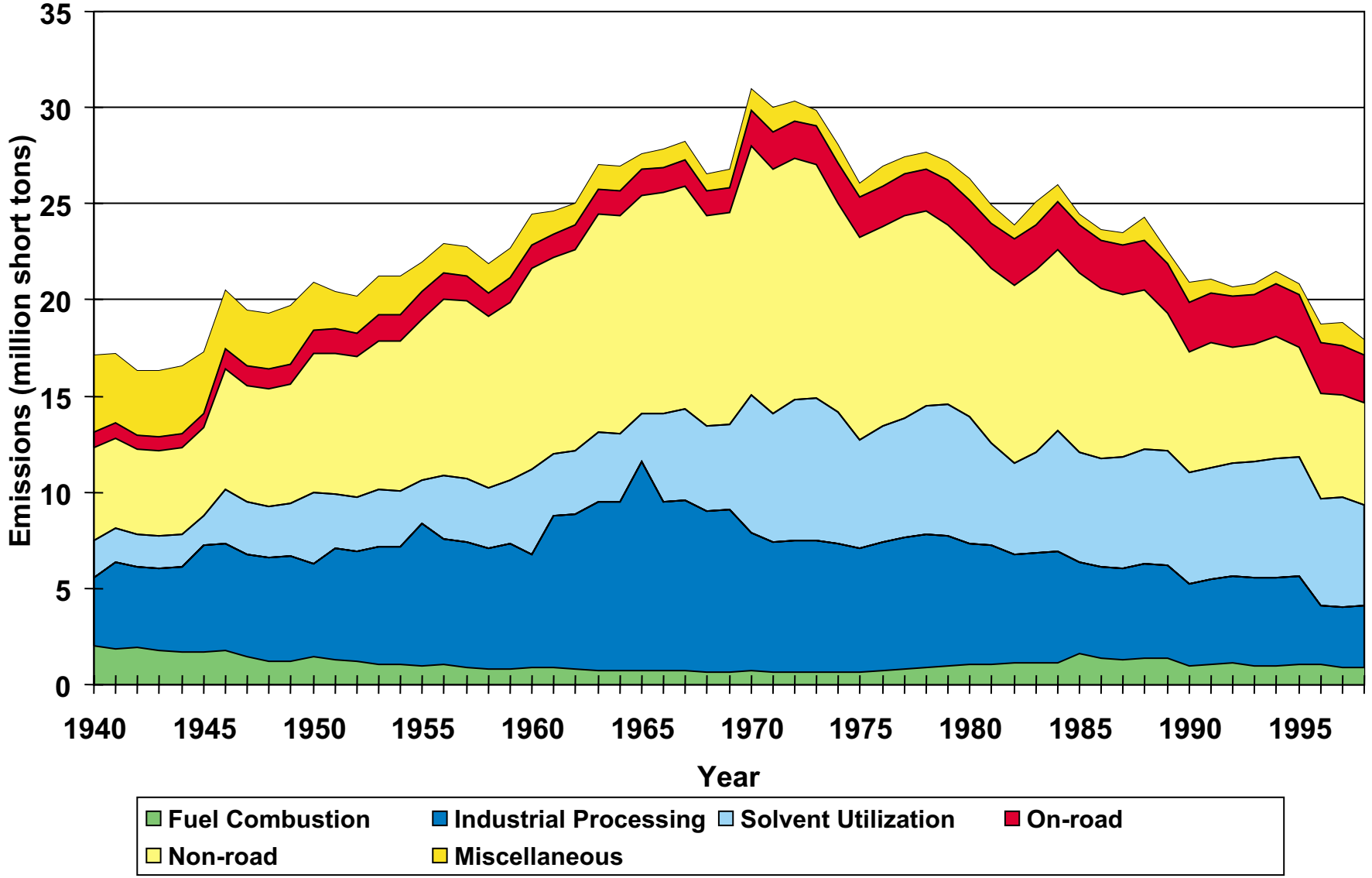
Note: Some fluctuations in the years before 1970 are the result of different methodologies

Figure 3-3. Trend in NITROGEN OXIDE Emissions, 1940 to 1998



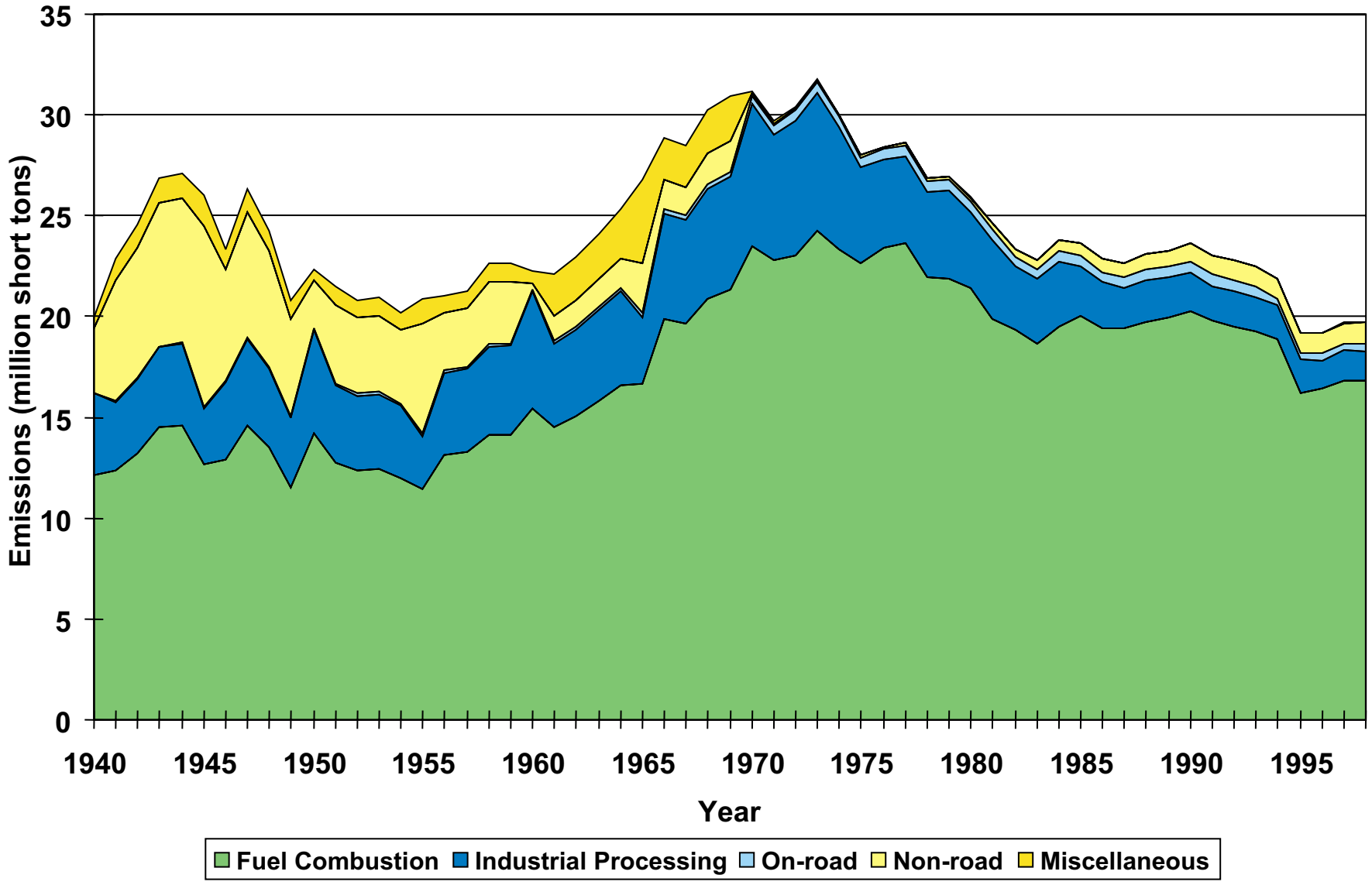
Note: Some fluctuations in the years before 1970 are the result of different methodologies

Figure 3-4. Trend in VOLATILE ORGANIC COMPOUND Emissions, 1940 to 1998



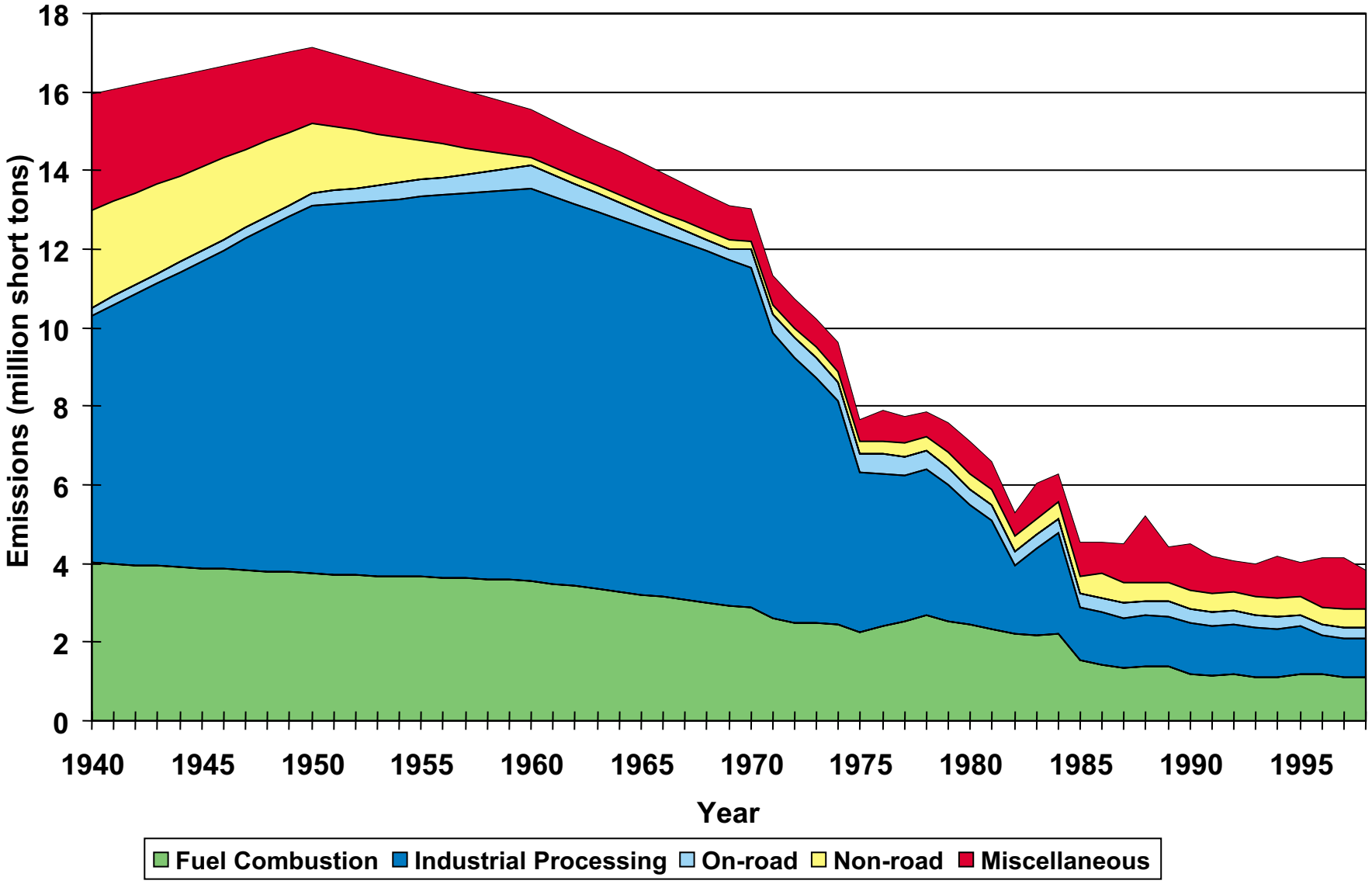
Note: some fluctuations in the years before 1970 are the result of different methodologies

Figure 3-5. Trend in SULFUR DIOXIDE Emissions, 1940 to 1998



Note: Some fluctuations in the years before 1970 are the result of different methodologies

Figure 3-6. Trend in PARTICULATE MATTER (PM_{10}) Emissions Excluding Fugitive Dust Sources, 1940 to 1998



Note: Some fluctuations in the years before 1970 are the result of different methodologies

Figure 3-7. Trend in Directly Emitted PARTICULATE MATTER ($PM_{2.5}$) Emissions Excluding Fugitive Dust Sources, 1990 to 1998

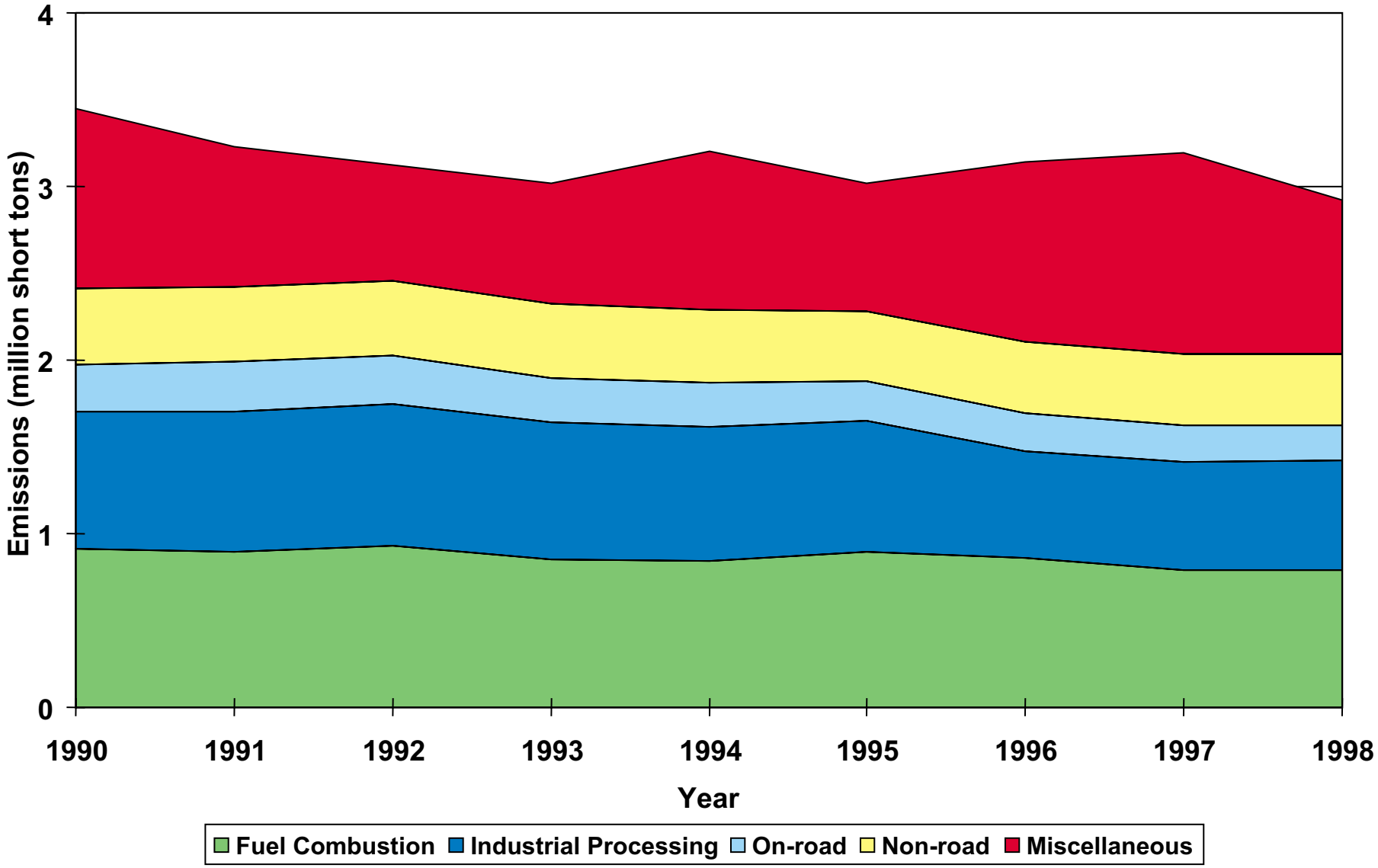


Figure 3-8. Trend in LEAD Emissions, 1970 to 1998

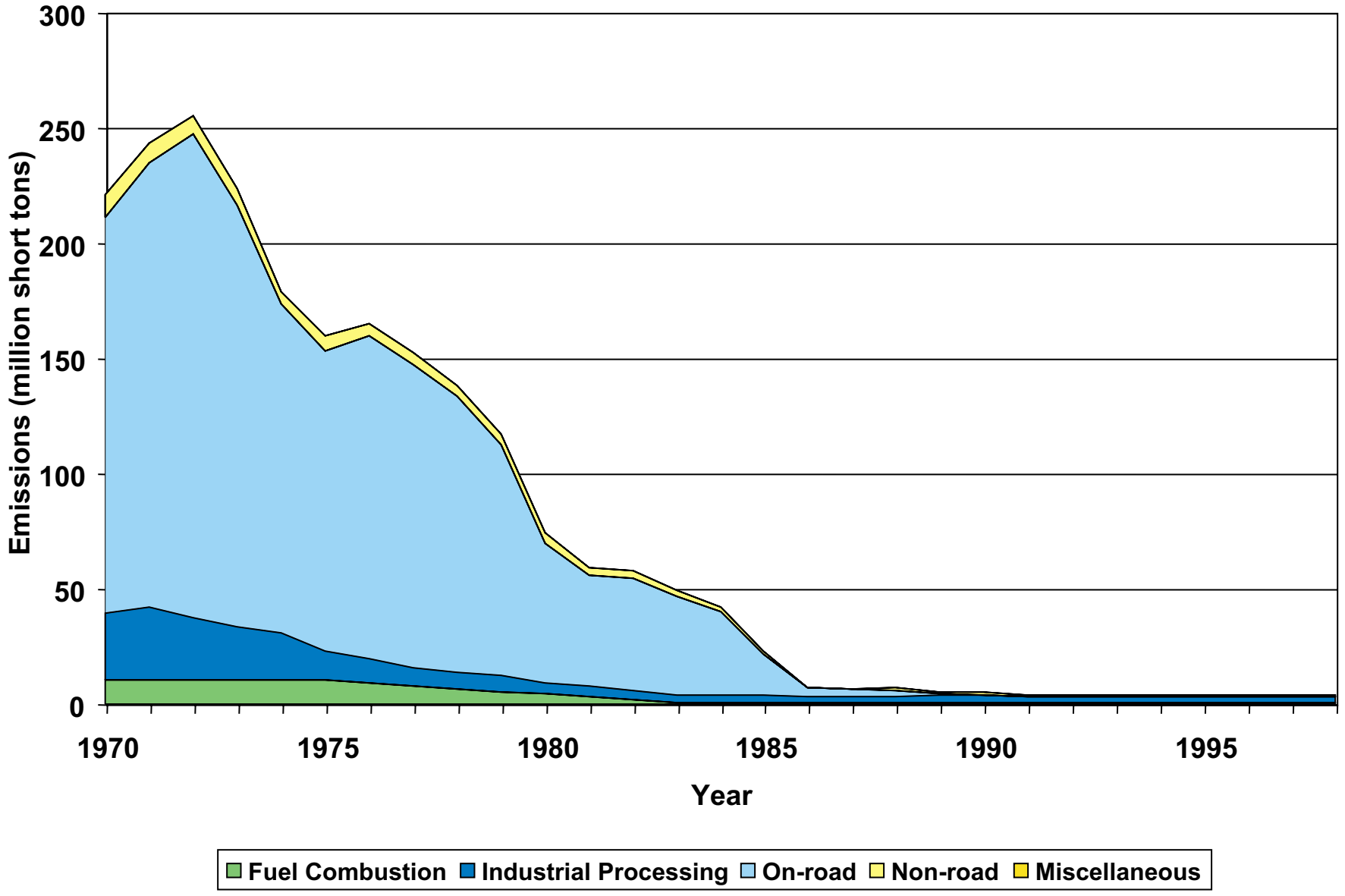
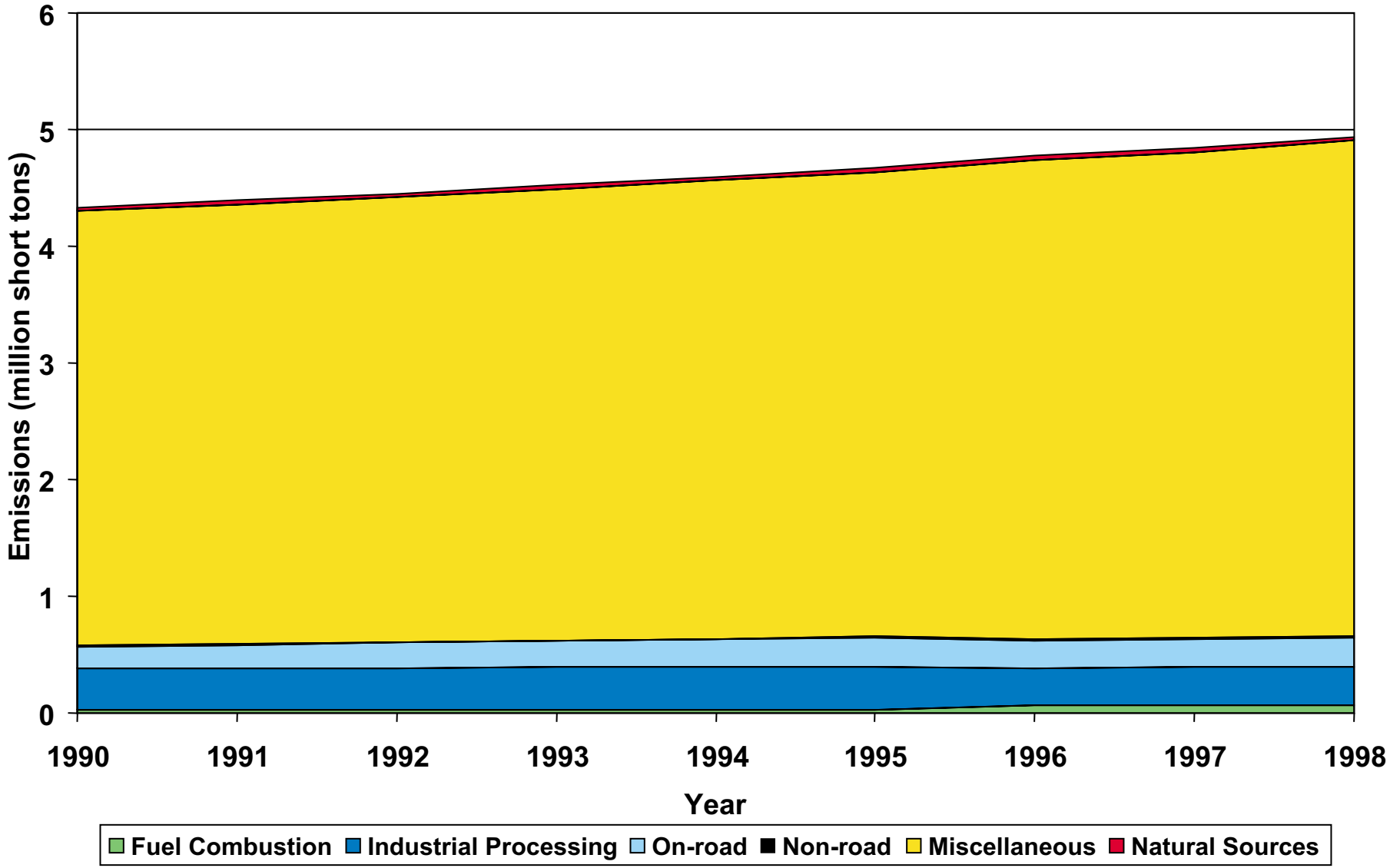


Figure 3-9. Trend in AMMONIA Emissions, 1990 to 1998



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